ERDC/GSL TR-14-33

Geotechnical and Structures Laboratory

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Geophysical Surveys for Detecting Anomalous Conditions, Algiers Canal Levees, New Orleans, Louisiana

José L. Llopis and Joseph B. Dunbar

August 2014

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Final report

Prepared for U.S. Army Engineer District, New Orleans
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Abstract

This report presents the results of a geophysical study performed to locate buried debris within the levees on the west side of Algiers Canal approximately 5 miles south of downtown New Orleans, LA. The levees are located adjacent to industrial and metal fabricating businesses. Reportedly, metallic debris, rubber hoses, concrete chunks, large pockets of shells, and other rubble have been found in these levees. A concern arose that debris and/or unmarked utilities located beneath or buried near the toe of the levees could affect the performance of the levee during flooding events. If a pipe or conduit exists under or within the levee, a possibility exists that it may fill with water during a flood event. If it does, and the conduit fails, it is possible that it may cause the levee to collapse either by piping material from within the levee or cause slope stability problems. It is also possible that buried utilities can act as potential seepage paths through the levee during high-water events. Buried debris and utilities need to be accurately located so that they can be removed or, in the case of a buried utility, rerouted or filled with grout. An electromagnetic (EM) induction survey using a Geonics EM31 terrain conductivity meter was conducted along the crest, slopes, and toes of the levee to locate anomalous conditions indicative of buried material. EM31 anomalies, presumed to be the location of buried debris, were mapped, and their coordinates tabulated for further interrogation.

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Preface

This report describes a study commissioned by the U.S. Army Engineer District, New Orleans, and conducted by the U.S. Army Engineer Research and Development Center (ERDC) to map buried debris beneath and near the levees on the west side of Algiers Canal, New Orleans, LA, using surface-based geophysical methods. The Project Manager was Joe Dziuk, U.S. Army Engineer District, Rock Island. The work was performed during the period 23 through 28 June 2009 and published under the Infrastructure Technology Program.

The work was performed by the Geotechnical Engineering and Geosciences Branch (GEGB) of the Geotechnical and Structures Division (GSD), U.S. Army Engineer Research and Development Center, Geotechnical and Structures Laboratory (ERDC-GSL). At the time of publication, Chad A. Gartrell was Chief, GEGB; Bartley P. Durst was Chief, GSD; and Dr. Michael K. Sharp was the Technical Director for Water Resources Infrastructure. Dr. Jackie Pettway of the Coastal and Hydraulics Laboratory was the technical monitor for the Infrastructure Technology Program. The Deputy Director of ERDC-GSL was Dr. William P. Grogan and the Director was Dr. David W. Pittman.

COL Jeffrey R. Eckstein was the Commander of ERDC, and Dr. Jeffery P. Holland was the Director.

Unit Conversion Factors

Multiply	By	To Obtain
feet	0.3048	meters
miles (US statute)	1,609.347	meters

Executive Summary

Subsurface geophysical methods can be broadly characterized as an attempt to “see” beneath the ground surface in a non-destructive and non-intrusive manner without digging up the ground. In any area, the ground soils have naturally-occurring physical properties associated with them. The measurement of these naturally-occurring properties may be considered the background readings or “normal” readings for a given area. In reality, what the geophysical instrument detects are significant changes (anomalies) in one of these naturally-occurring physical parameters. The most effective and efficient survey method for the conditions encountered along Algiers Canal, based on the authors’ experience on conducting similar surveys on other New Orleans levees, was the electromagnetic (EM) induction survey method.

The general process employed for field data collection was to traverse the ground along the levee toes, slopes, and crest with a Geonics EM31 terrain conductivity meter. Data were collected approximately at 1-ft intervals along each traverse. The data and their locations were recorded. The data were analyzed and anomalous locations were mapped and prioritized for further investigation. The final determination of the actual nature and depth of these anomalies is only possible through excavation and visible inspection. The use of geophysical techniques for anomaly detection enables the extent of subsequent excavating to be minimized by more accurately targeting areas with underlying debris.

1 Introduction

1.1 Background

Levees in urban areas are many times located over or near buried debris and utilities. During flooding events, it is conceivable that utilities encased in conduits crossing beneath levees or buried near levee toes may become in-filled with water from floodwater on the landside of the levee. If one of these water-filled conduits were to fail beneath or near the levee toe during a flood event, a piping-induced catastrophic failure of the levee would be possible. It is also possible that buried debris and utilities can serve as potential seepage paths through the levee during high-water events. Currently, the U.S. Army Engineer District, New Orleans is enlarging levees in an urban area located on the west side of Algiers Canal approximately 8 miles south-southwest of downtown New Orleans, LA. During levee enlarging, the New Orleans District contractor located and removed buried debris within the levee during construction operations. However, given the length of time the levees had been in place and the urban expansion into this area, completeness of debris removal is in doubt. All debris must be accurately located so that it can be excavated and removed.

1.2 Objective

At the request of the New Orleans District, personnel of the U.S. Army Engineer Research and Development Center (ERDC) conducted a geophysical investigation along a stretch of levee located on the west bank of the Algiers Canal. The study area, designated West Bank & Vicinity (WBV) -6a.1 by New Orleans District, was approximately 4.7 miles in length and extended from the confluence of the Harvey and Algiers canals north to Highway 23, as shown in Figure 1. The primary objective of the investigation was to map the location of electromagnetic (EM) anomalies presumably associated with the location of buried debris and utilities beneath and along the toes of the Algiers Canal levees. The investigation was performed during the time period 23 through 28 June 2009.

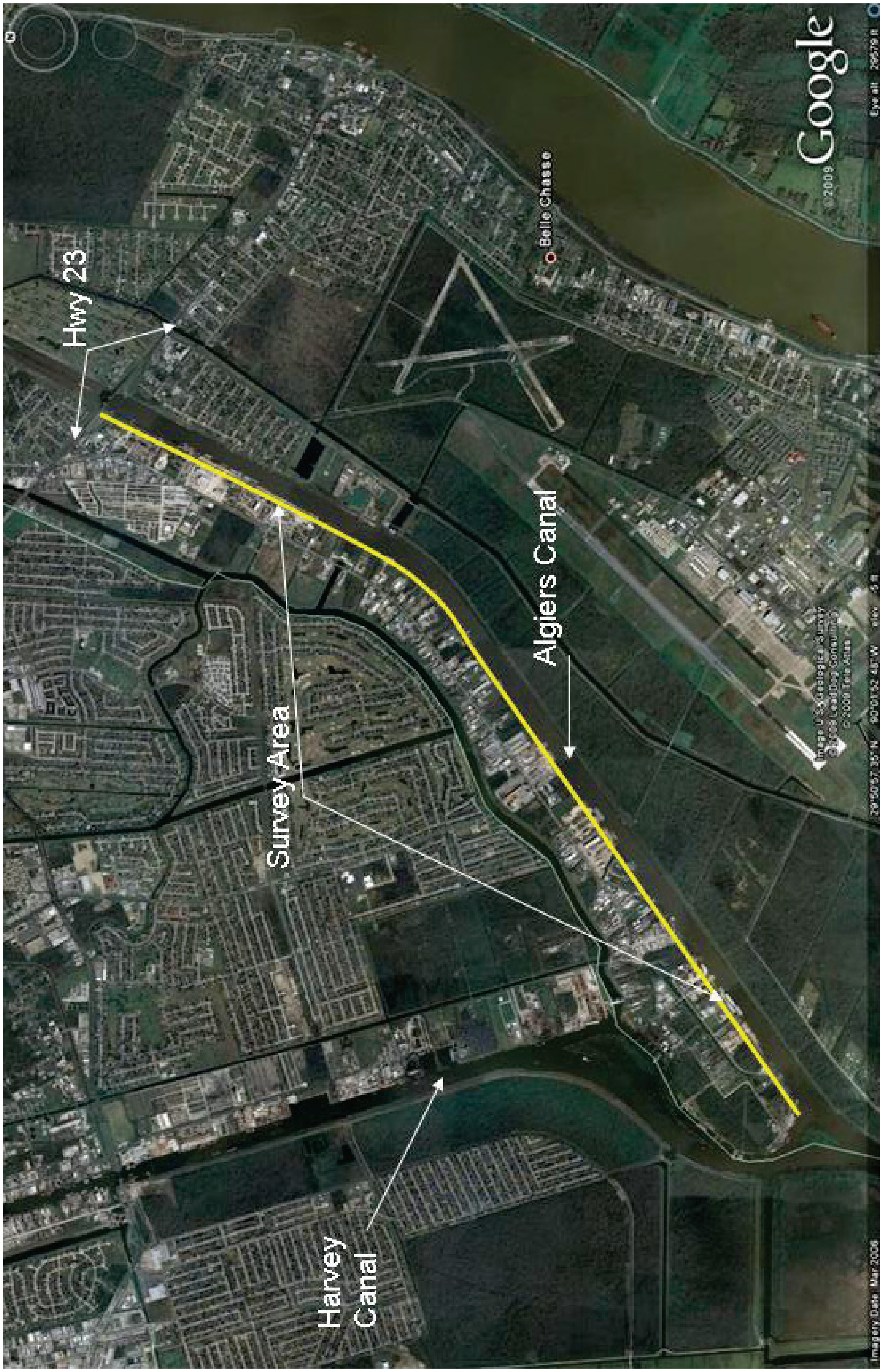


Figure 1. Site map of the survey area, New Orleans, LA.

2 Geophysical Test Principles and Field Procedures

EM induction is used to measure the apparent electrical conductivity (inverse of electrical resistivity) of subsurface materials and for detecting buried metallic items. Electrical conductivity is a measure of the degree to which the soil conducts an electrical current and can be used to infer geologic materials and the location of the water table.

A survey was conducted along the Lake Pontchartrain levees in 2007 to locate underground utilities (Llopis and Simms 2014). A Geonics, Ltd. terrain conductivity meter, Model EM31, was selected for this survey based on a comparison of the results from a magnetometer, a Geonics EM61 metal detector, and an EM31 used in previous studies on other New Orleans levees.

The EM31 consists of a set of co-planar transmitter (Tx) and receiver (Rx) coils separated approximately 12 ft apart. An alternating current is passed through the Tx coil, thus generating a primary time-varying magnetic field. This primary field induces eddy currents in subsurface conductive materials. The induced eddy currents are the source of a secondary magnetic field, which is detected by the Rx coil along with the primary field.

Two components of the induced magnetic field are measured by the EM system. The first is the quadrature phase, sometimes referred to as the out-of-phase or imaginary component. Apparent ground terrain conductivity is determined from the quadrature component. Disturbances in the subsurface caused by compaction, in-filled abandoned channels, soil removal and fill activities, buried objects, or voids may produce conductivity readings different from background values, thus indicating anomalous areas. The units of apparent ground conductivity are measured in milliSiemens per meter (mS/m). The in-phase component is sensitive to metallic objects, and therefore is useful when looking for buried metal, such as metal pipes and electrical wires. When measuring the in-phase component, the true zero level is not known, because the reference level is arbitrarily set by the operator. Therefore, measurements collected in this mode are relative to an arbitrary reference level and have units of parts per thousand (ppt).

Under optimal conditions, the EM31 has an effective depth of investigation of about 20 ft (Geonics 1980). The EM31 meter reading is a weighted average of the earth's conductivity. A thorough investigation to a depth of about 12 ft is usually possible, but below this depth the effect of electrically conductive objects becomes more difficult to distinguish.

Data were collected along six survey lines that ran parallel to the axis of the levee. One line each was located along the landside and riverside toes, crest, riverside midslope, and two lines along the protected slope. EM data were collected at approximately 1-ft intervals along each survey line. Position data were collected with the aid of a global positioning system (GPS) that was positioned above the center of the instrument. The GPS is reported to have accuracy to within 3 ft.

For this study, the EM31 was mostly hand-towed using a light-weight non-metallic cart specially designed for this instrument (Figure 2). In areas, where cart accessibility was a problem, the instrument was carried at hip level as shown in Figure 3. In both cases, the long axis of the instrument was oriented parallel to the line direction during the survey.

Figure 2. Cart-mounted EM31 terrain conductivity meter.

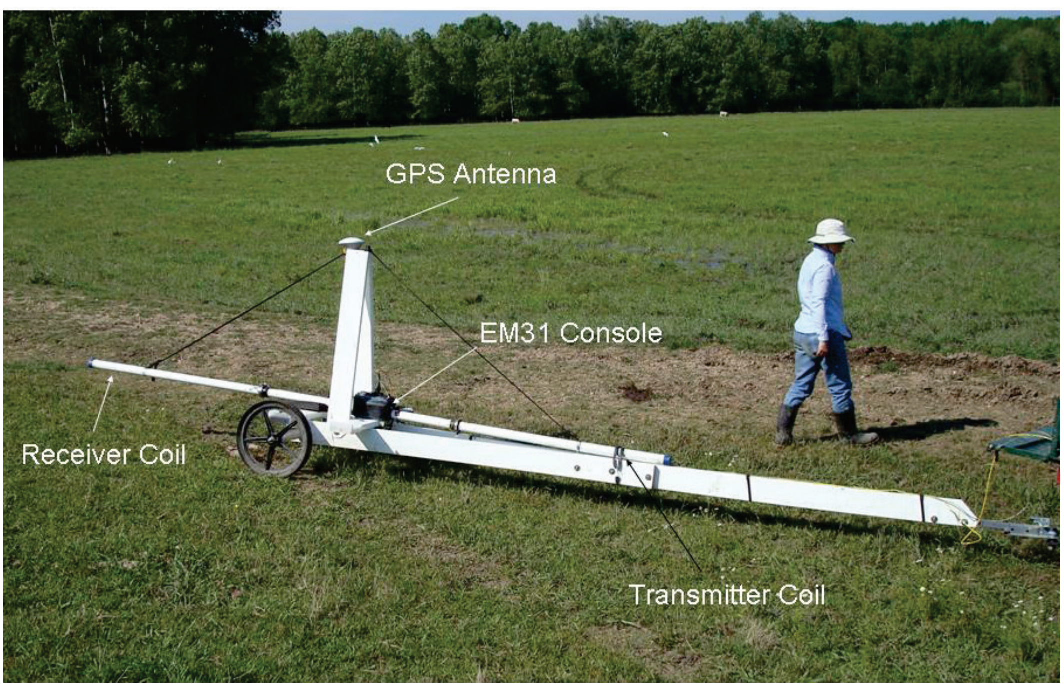
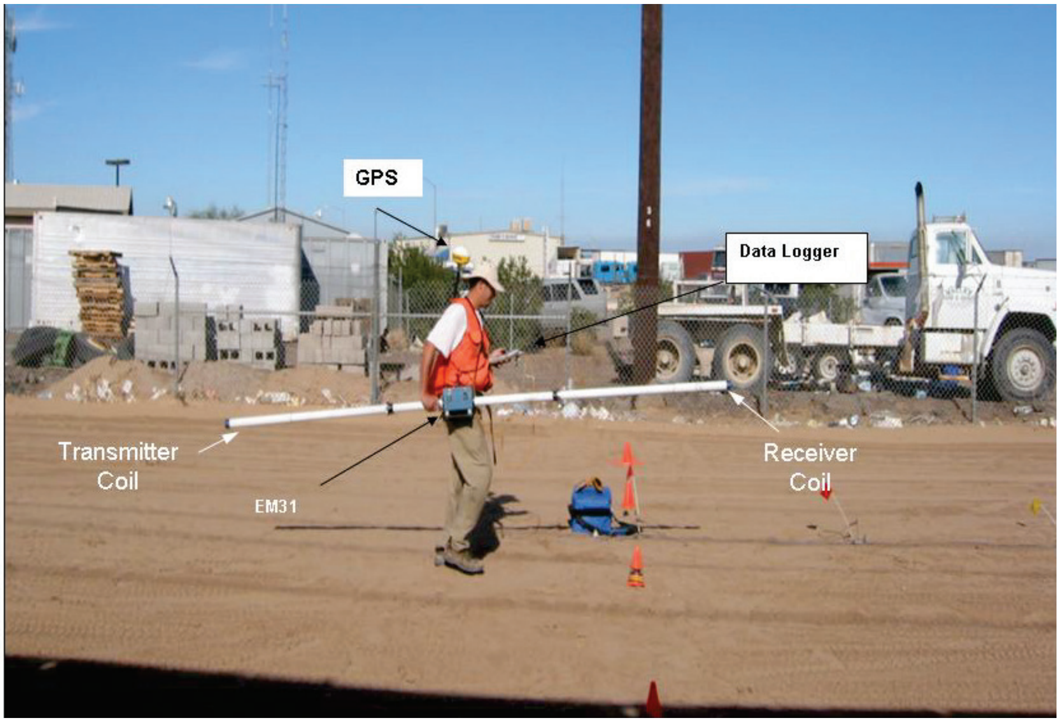


Figure 3. EM31 conductivity meter being carried during a typical survey.



3 Geophysical Test Results

For presentation purposes, the study area was divided into eight sections as shown in Figure 4. The EM data were plotted as contour maps of conductivity and in-phase values. The plotted data were examined, and those areas that appeared to have values significantly greater than background (anomalies) were noted on the plot. The positions of many visible cultural features that could potentially affect the survey readings, such as ramps, barrels, metal pipes, were recorded. During the data analysis, it was noted that many of the initially interpreted anomalies were caused by ramps crossing the levee.

The in-phase and conductivity maps for each section are presented in Appendices A and B, respectively. The conductivity and in-phase maps show the anomaly location (indicated with a filled circle) and a corresponding anomaly number (indicated with the "#" symbol). To the right of each circle, is a number ranging from 1 to 5, corresponding to the anomaly's priority for further investigation. The priority number is based on the intensity and size of the anomaly as well as its location. A priority value of 1 indicates the highest priority. In cases where the cause of interpreted anomaly is presumed to be known, such as caused by material differences from ramps crossing the levee, a priority of 5 is assigned to that anomaly. Also, a description of the anomaly is provided to the right of the numbered anomaly. Images of the survey maps were overlain on Google Earth imagery to aid in orienting anomaly locations and are discussed next in the in-phase and conductivity survey results section. The stationings presented in this report were estimated using copies of construction drawings and are probably accurate to within 10 to 20 ft. Tables in Appendices C and D provide anomaly number, corresponding Louisiana State Plane and geographic coordinates, stationing, priority, and anomaly description for the in-phase and conductivity surveys, respectively.

3.1 In-phase survey results

3.1.1 Section 1

Section 1 extends from the Highway 23 tunnel (station 980+00) southwesterly to approximate station 1018+21. The survey results for Section 1 are presented in Figure 5. No priority 1 or 2 anomalies were interpreted for this

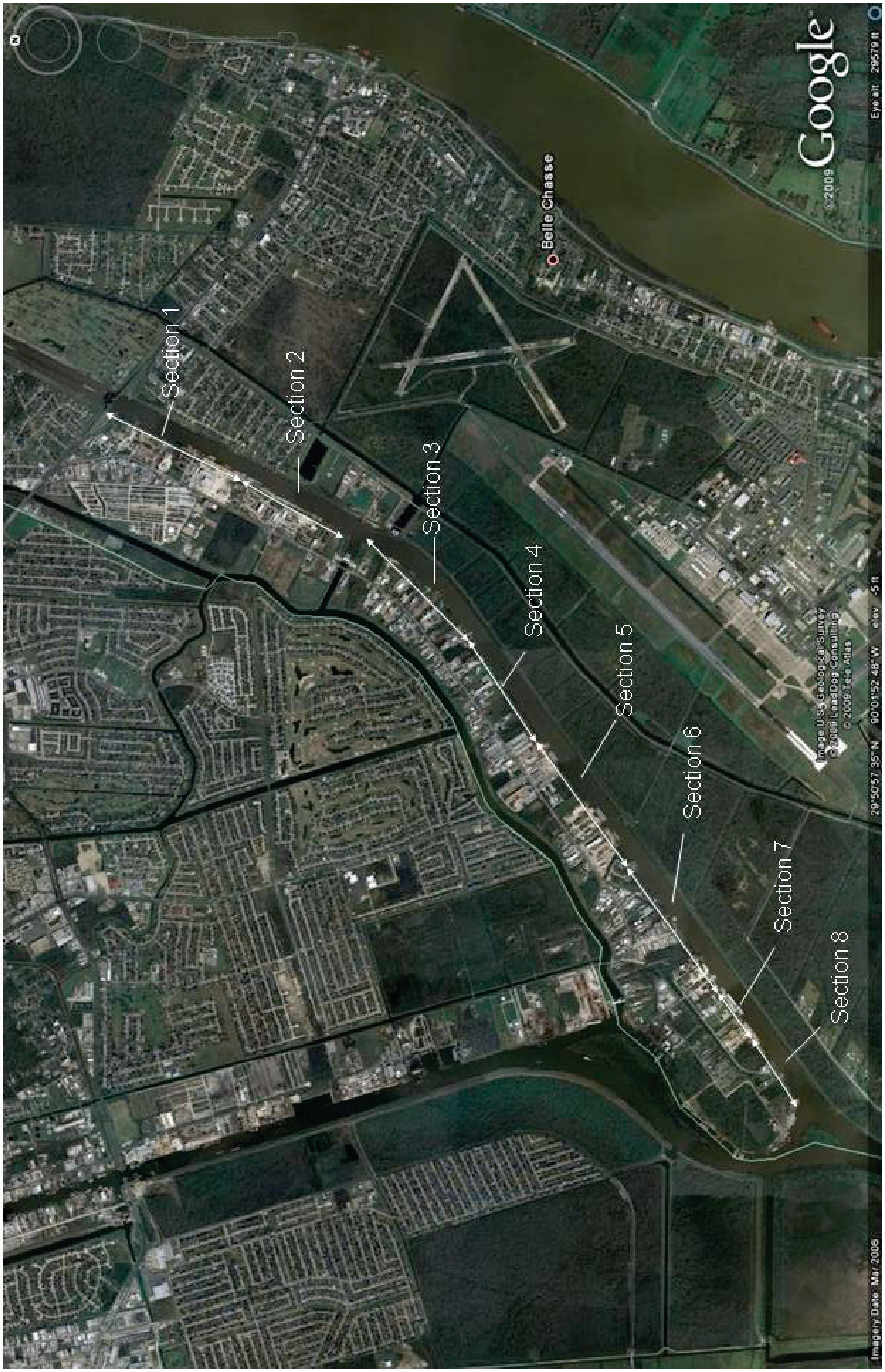
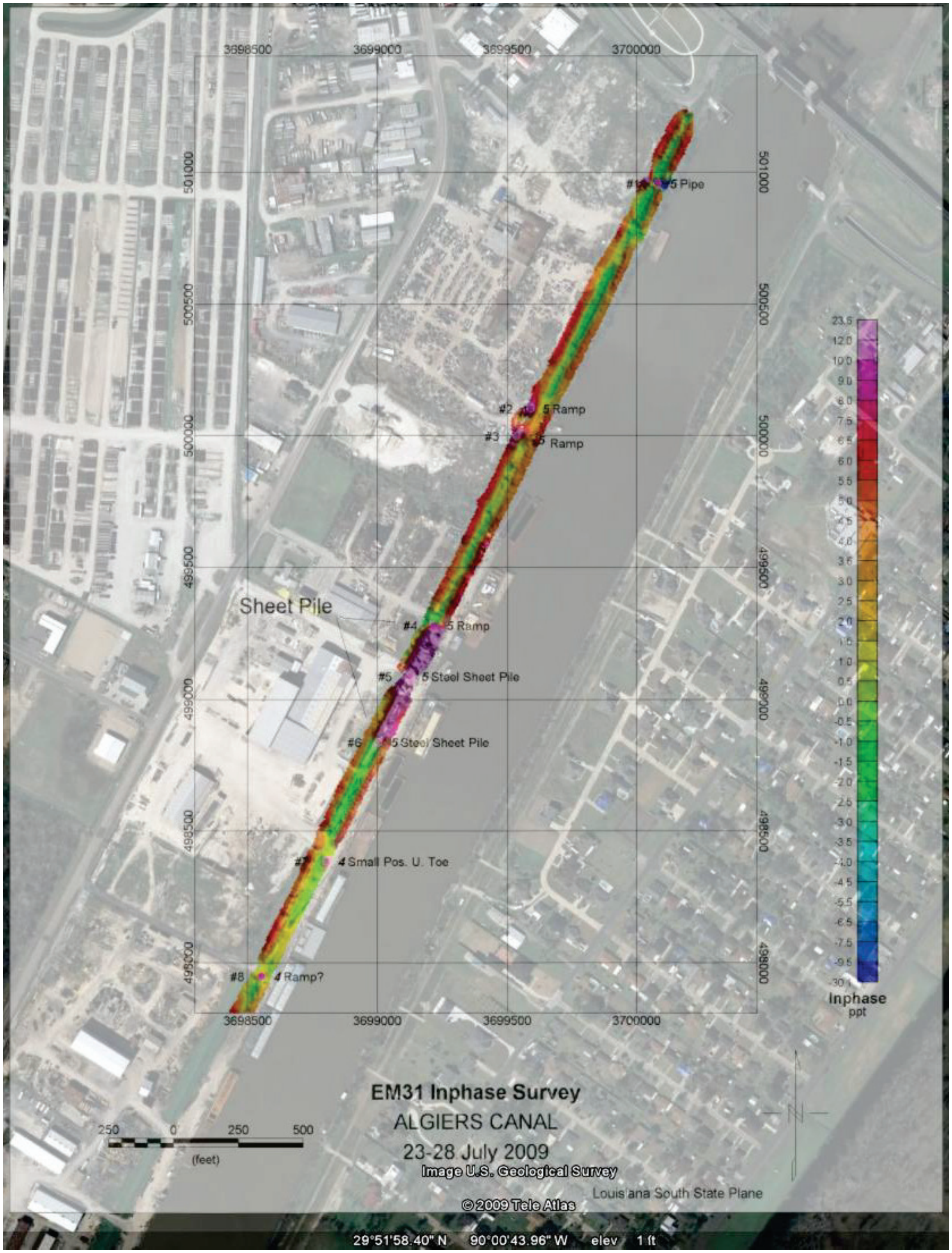


Figure 4. Site map showing survey sections.

Figure 5. EM31 in-phase survey results overlaid on Google Earth image, Section 1.



section. The highest priority given to an anomaly in this section was a priority of 4. A steel sheet pile, located between approximate stations 1001+81 and 1006+78, is clearly evident (hot pink area). With the exception of the area in the vicinity of the steel sheet pile, the values along the center line of the levee are fairly consistent indicating very little or no metallic debris within the levee. However, the values along the toes of the levee have considerable variability. This variability is mainly caused by the effects of nearby metallic objects (e.g., cranes, metal buildings, pipes, reinforced concrete slabs). The anomalies along the toes are not considered to be a threat to the integrity of the levee and thus are not noted.

3.1.2 Section 2

Section 2 continues in a southeasterly direction between approximate stations 1018+21 and 1044+18. The results are shown in Figure 6. A priority 2 anomaly is indicated for anomaly #11 at approximate station 1022+90 and may be caused by a small buried metallic object. A cluster of priority 3 anomalies (anomalies #14, #15, and #16) are shown near station 1029+48.

3.1.3 Section 3

The results of the in-phase survey conducted along Section 3 are shown in Figure 7. The site extends between approximate stations 1044+18 and 1086+64. This site had numerous ramps crossing the levee. Anomalies 24 and 28 were assigned a priority 1 designation and are located at approximate stations 1060+01 and 1064+65, respectively. These anomalies are linear in nature and cross the levee at right angles. It is not certain whether anomaly 28 coincides with a ramp location. If it does, this anomaly should probably be designated with a priority of 5.

3.1.4 Section 4

This section extends between approximate stations 1086+64 and 1116+53. Only three anomalies were interpreted as shown in Figure 8. A priority 2 anomaly was assigned to anomaly 31 located near station 1116+53. This anomaly may be caused by a buried or surface metallic object near the unprotected slope of the levee.

3.1.5 Section 5

This section stretches between approximate stations 1116+53 and 1154+48 and has two priority 1 and two priority 2 anomalies as shown in Figure 9.

Figure 6. EM31 in-phase survey results overlaid on Google Earth image, Section 2.

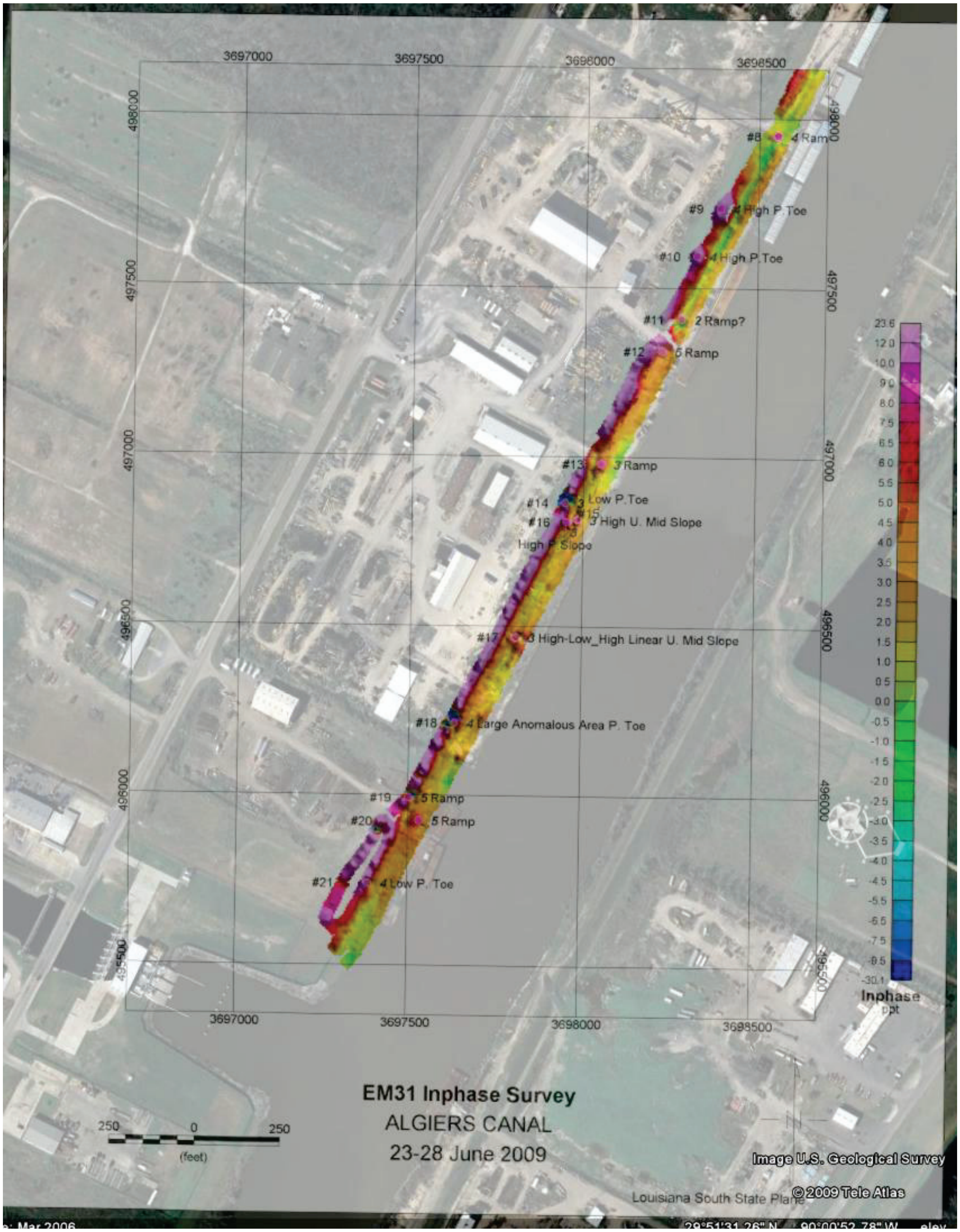
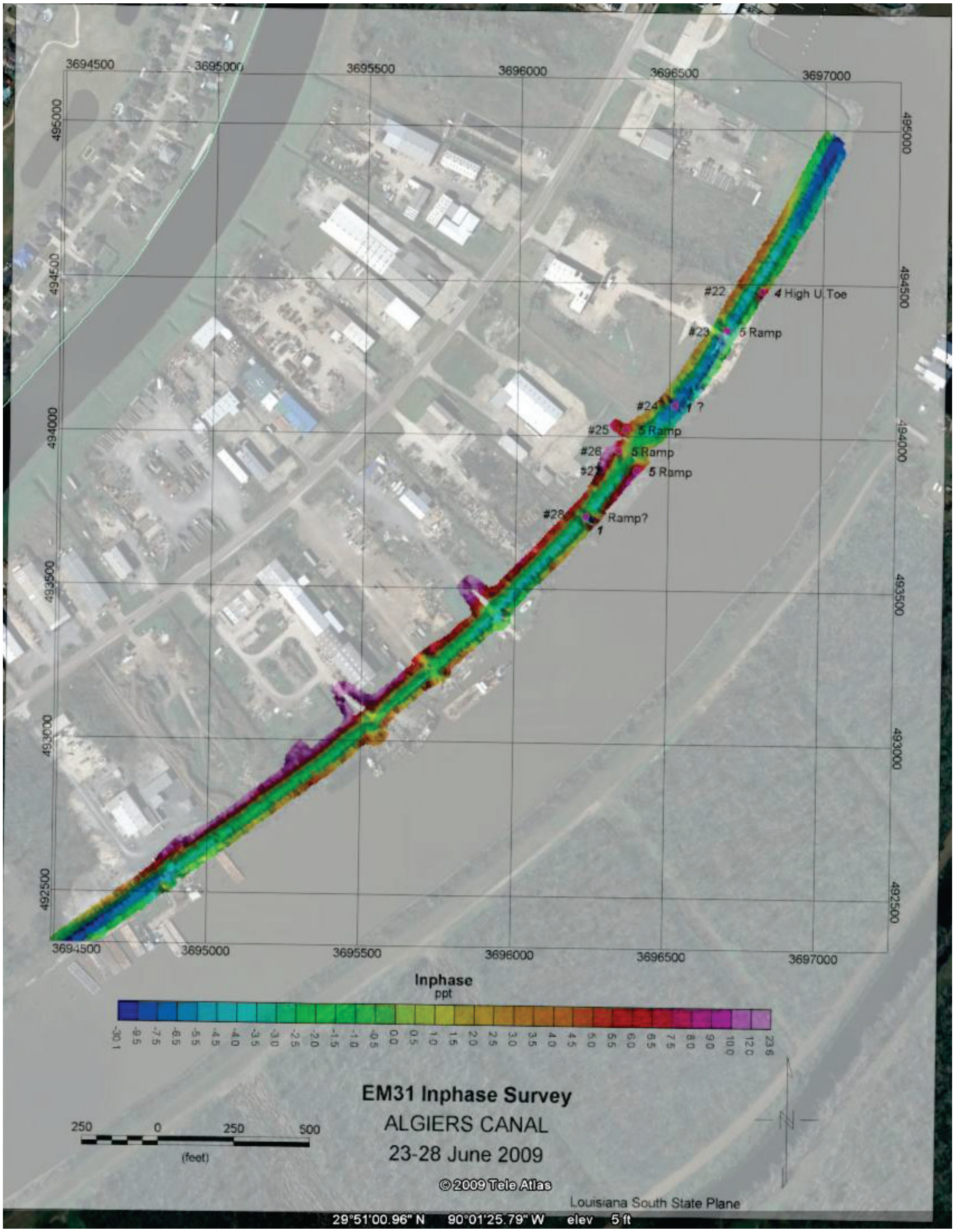


Figure 7. EM31 in-phase survey results overlaid on Google Earth image, Section 3.



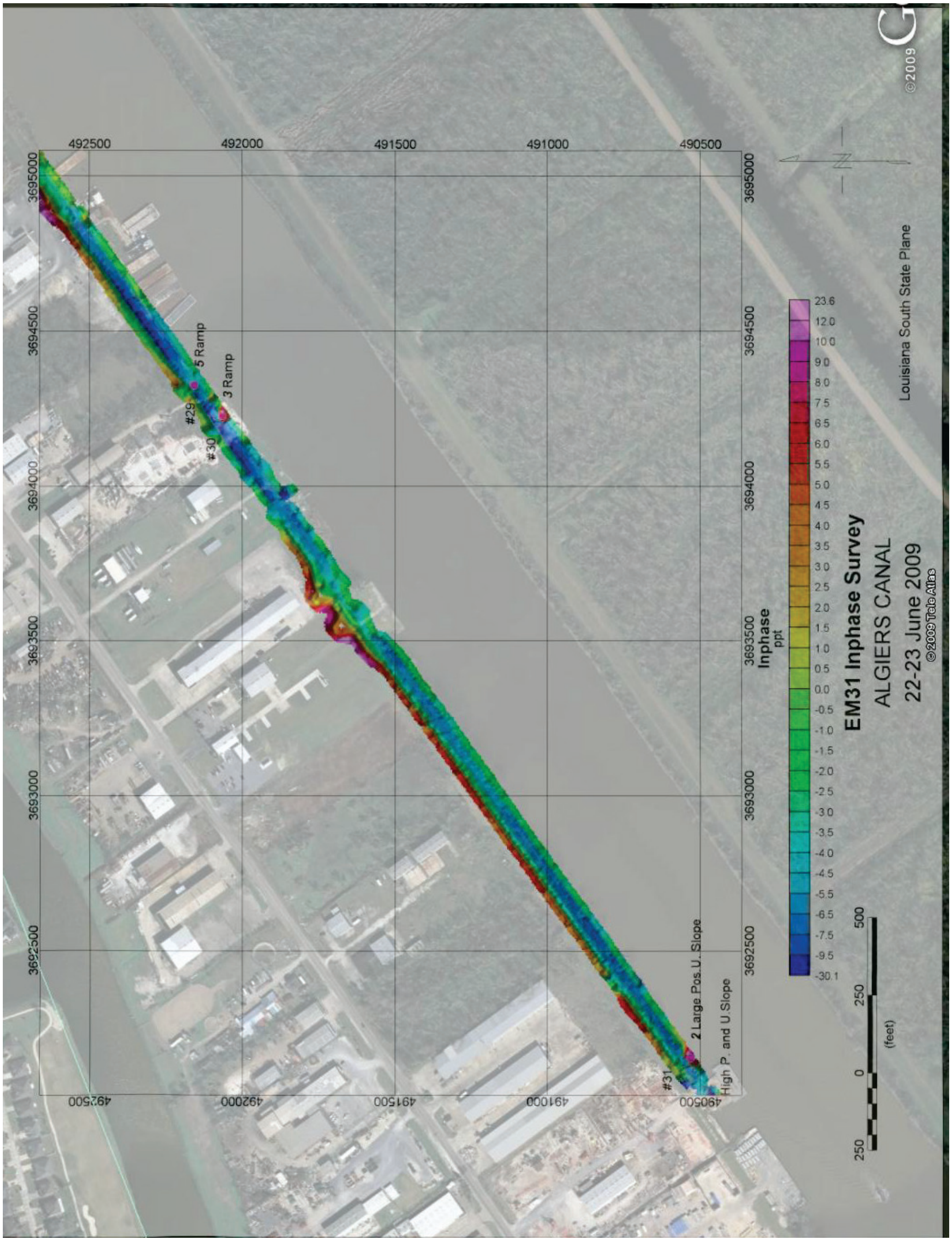
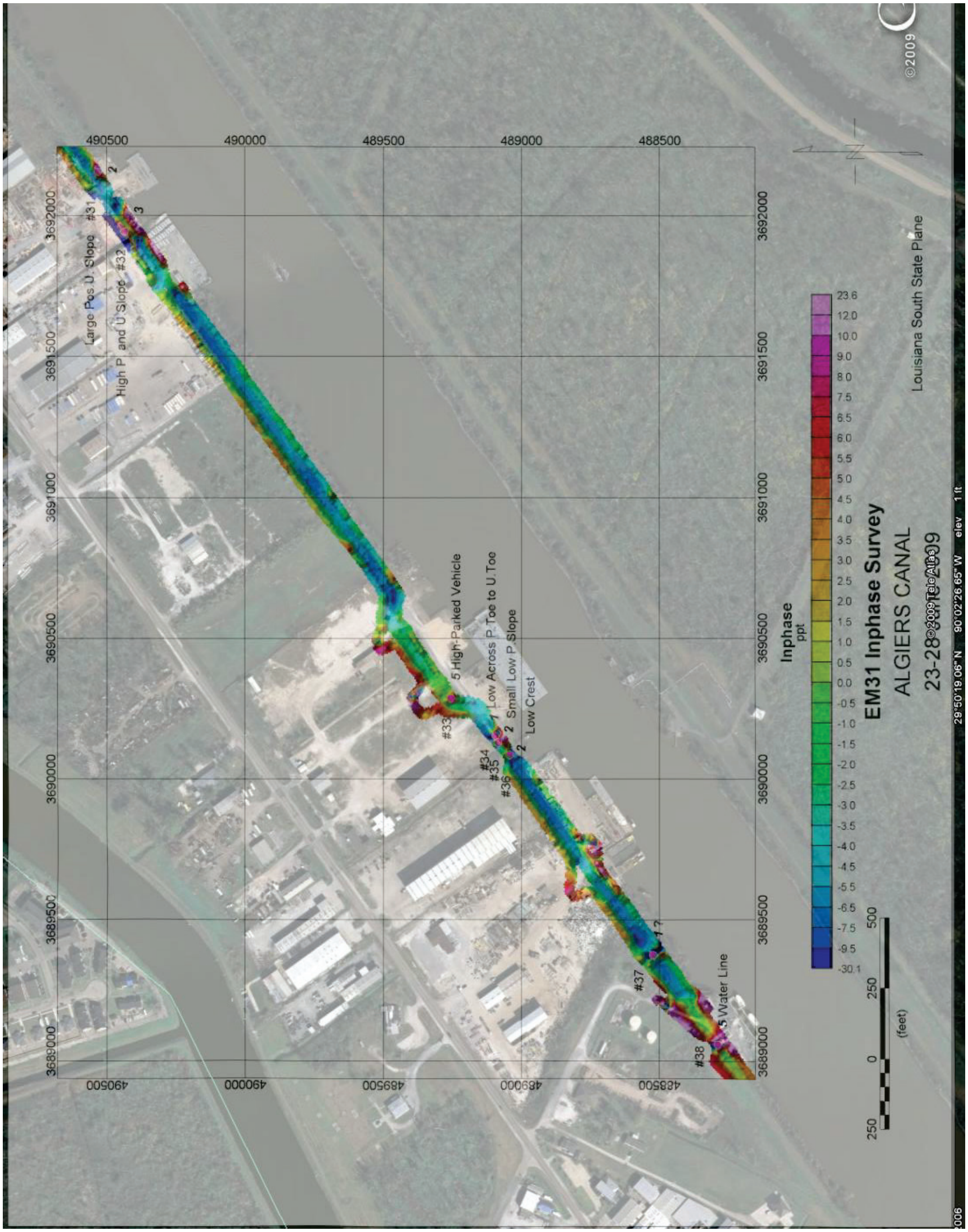


Figure 8. EM31 in-phase survey results overlaid on Google Earth image, Section 4.

Figure 9. EM31 in-phase survey results overlaid on Google Earth image, Section 5.



The priority 1 anomaly located at station 1141+21 (anomaly 34) indicates the possibility of an object crossing beneath the levee. Anomaly 35, a priority 2 anomaly, indicates a small anomaly located on the landside slope of the levee near station 1141+06. It is possible that anomalies 34 and 35 may be caused by the same object. Anomaly 37, a priority 1 anomaly (station 1150+86), is located approximately 25 ft southwest of an area marked with cable crossing signs. No indications of a buried cable were noted with the EM31 instrument when crossing the marked area, which is also characterized by a noticeable hump in the levee. However, approximately 20 to 30 ft southwest of the marked cable crossing area, the instrument indicated a strong response to a buried metallic object oriented perpendicular to the axis of the levee. The strong linearly-oriented anomaly located near station 1154+48, anomaly 38, is caused by a buried steel pipe that crosses the levee and is visible on the protected toe.

3.1.6 Section 6

This section stretches between approximate stations 1154+48 and 1194+31 (Figure 10). All of the anomalies in this section have priority numbers of 5, with the exception of anomaly 45 that has a priority of 3. The location of anomaly 45 coincides with the location of a ramp. However, there is an indication of a localized metallic object.

3.1.7 Section 7

Section 7 is located between approximate stations 1194+31 and 1211+26. Three anomalies were interpreted for this section as shown in Figure 11. Anomaly 48, located at station 1196+64, is a strong linear-shaped anomaly that crosses the levee. A hump crosses the levee center line directly over the location of the anomaly. It is presumed that this anomaly is caused by a buried nitrogen line indicated in the construction drawings.

3.1.8 Section 8

The southernmost section extends between approximate stations 1211+26 and 1229+44 (Figure 12). Anomalies 52 through 56 have priorities of 1 and 2 and are indicative of small metallic objects. This section of levee had not been raised at the time this survey was conducted.

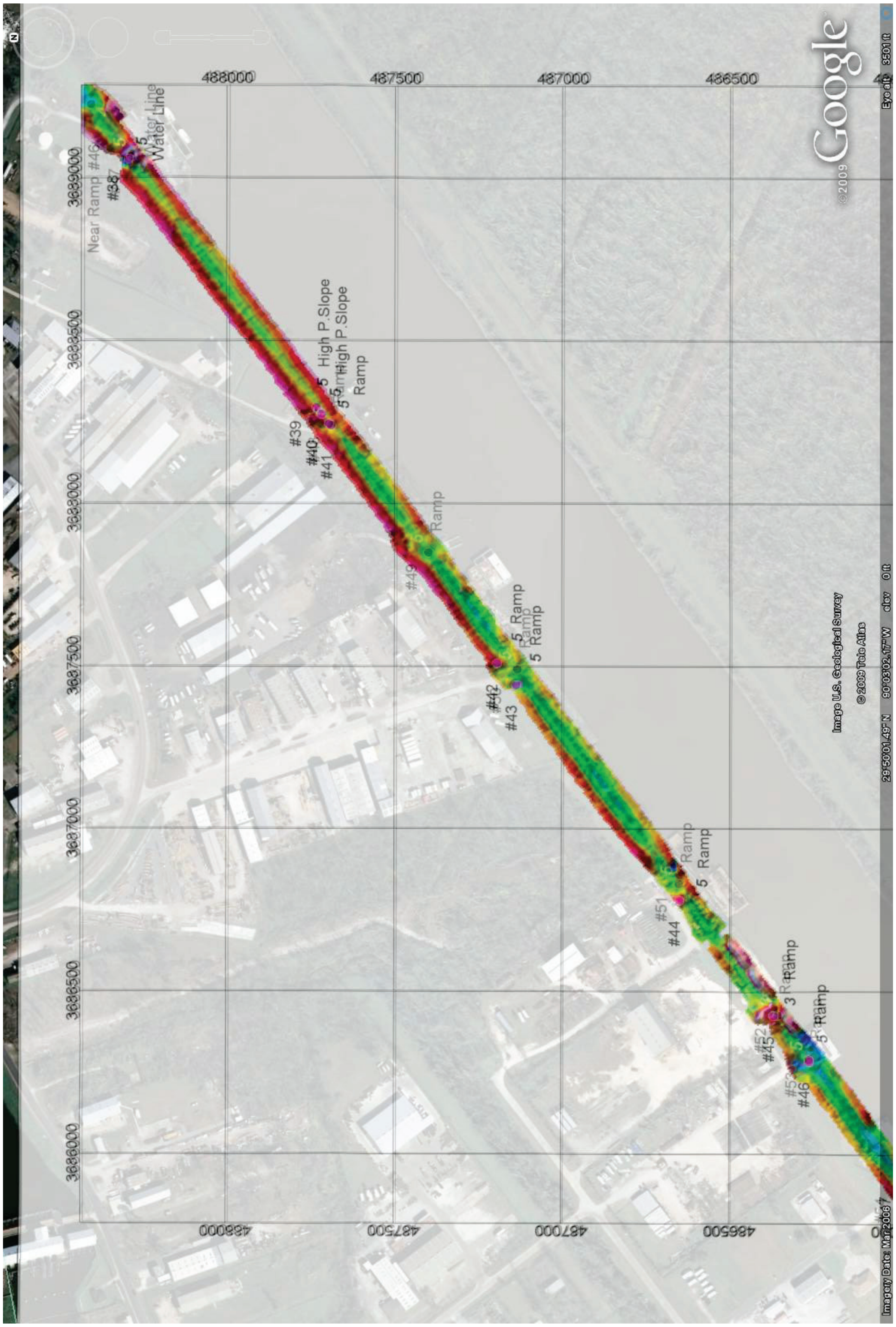


Figure 10. EM31 in-phase survey results overlaid on Google Earth image, Section 6.

Figure 11. EM31 in-phase survey results overlaid on Google Earth image, Section 7.

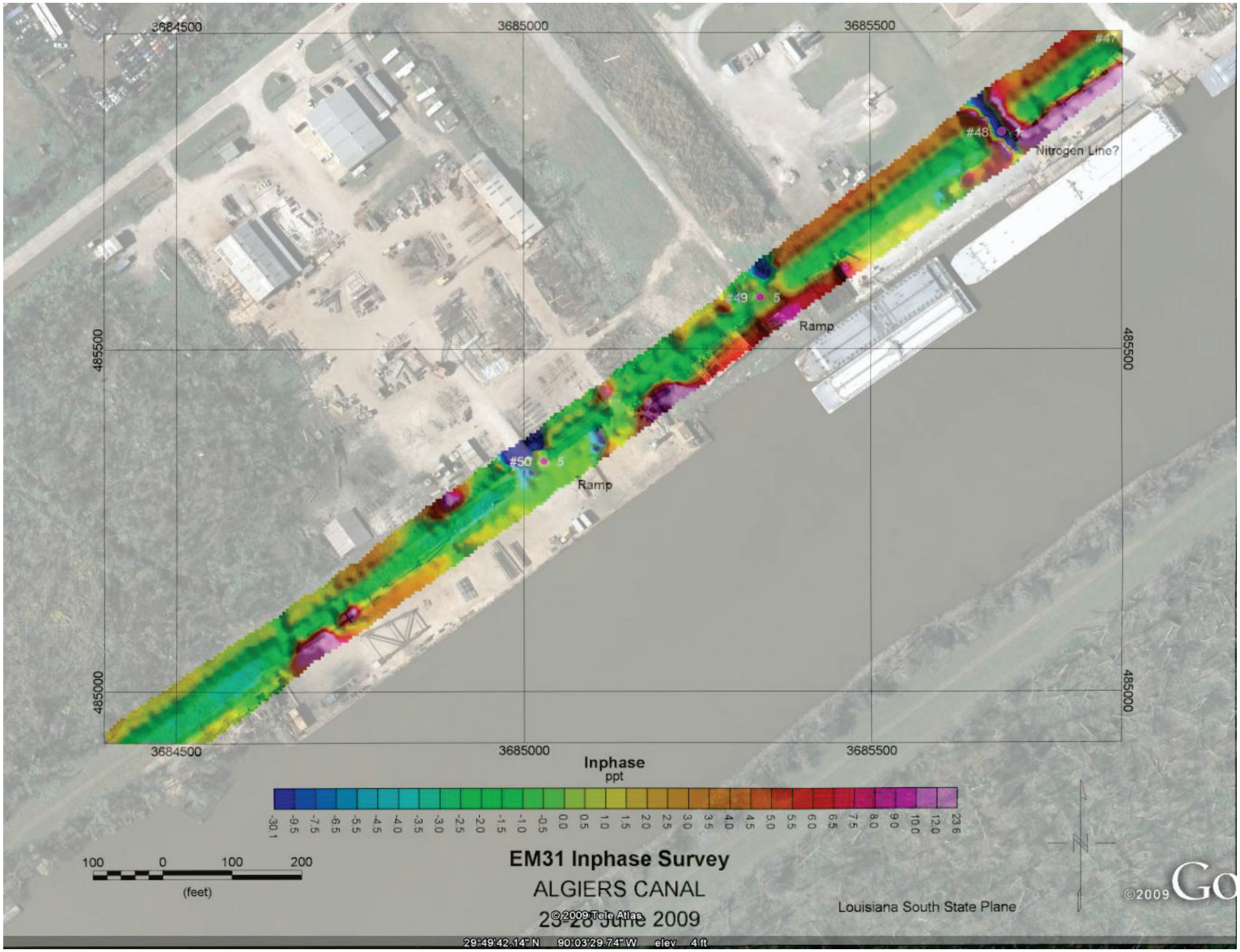
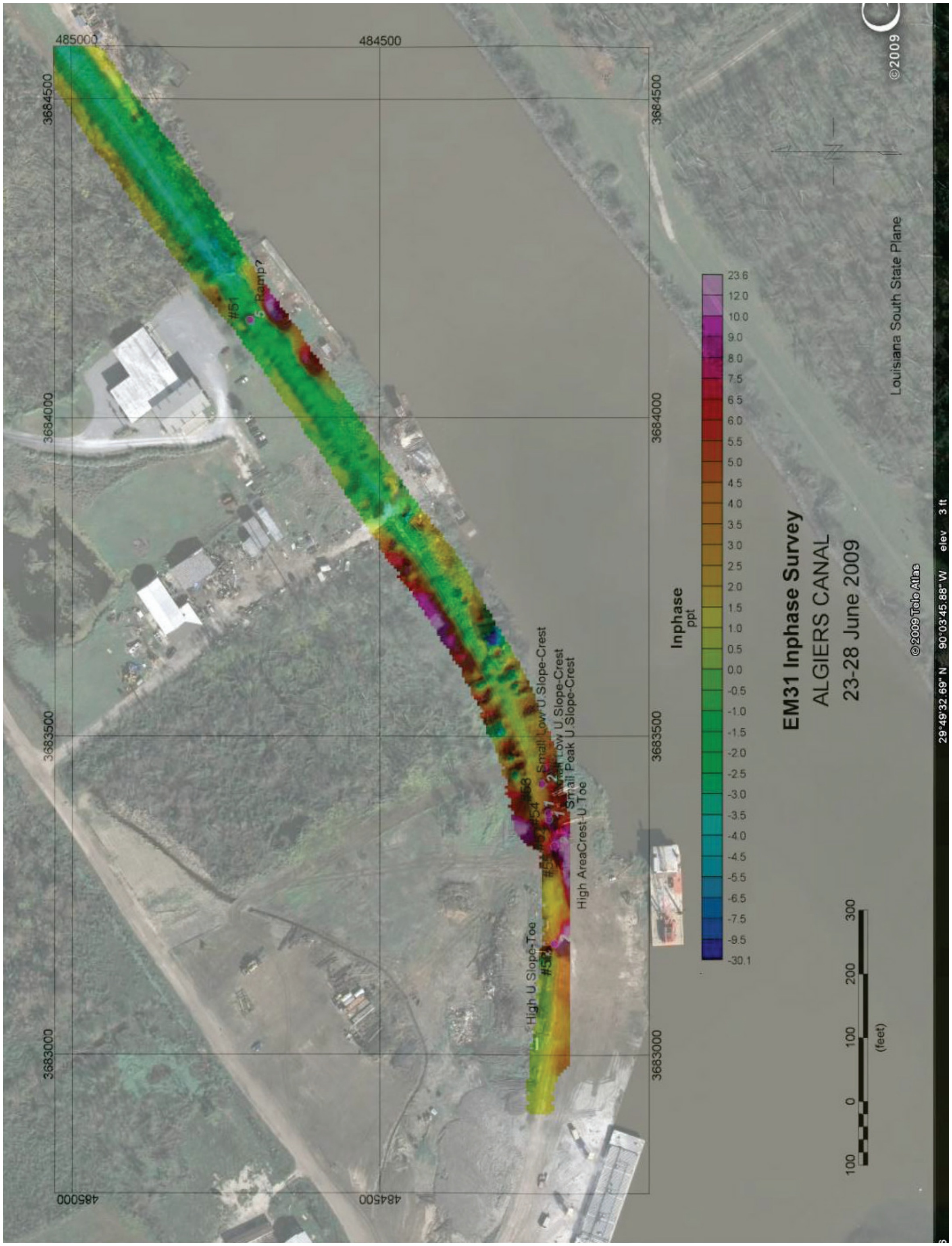


Figure 12. EM31 in-phase survey results overlaid on Google Earth image, Section 8.



3.2 Conductivity survey results

3.2.1 Section 1

Section 1 extends from the Highway 23 tunnel (station 980+00) southwesterly to approximate station 1018+21. The survey results for Section 1 are presented in Figure 13. No priority 1 or 2 anomalies were interpreted for this section. The highest priority given to an anomaly in this section was a priority of 4. As was the case for the in-phase survey, a steel sheet pile, located between approximate stations 1001+81 and 1006+78, is clearly evident. It is again noted, with the exception of the area in the vicinity of the steel sheet pile, that the values along the center line of the levee are fairly consistent indicating little or no metallic debris within the levee.

3.2.2 Section 2

Section 2 continues in a southeasterly direction between approximate stations 1018+21 and 1044+18. The results are shown in Figure 14. A priority 2 anomaly is indicated for anomaly 13 at approximate station 1023+02 and may be caused by a small buried metallic object.

3.2.3 Section 3

The results of the conductivity survey conducted along Section 3 are shown in Figure 15. The site extends between approximate stations 1044+18 and 1086+64. This site had numerous ramps crossing the levee. Anomalies 22 and 25, assigned a priority 1 designation, are located at approximate stations 1060+04 and 1064+65, respectively. These anomalies are linear in nature and cross the levee at right angles. It is not certain whether anomaly 25 coincides with a ramp location. If it does, this anomaly should probably be designated with a priority of 5.

3.2.4 Section 4

This section extends between approximate stations 1086+44 and 1116+53 (Figure 16). The values along the crest of the levee were fairly consistent with the exception of the ramp areas and the newly constructed levee area near station 1098+00.

Figure 13. EM31 conductivity survey results overlaid on Google Earth image, Section 1.

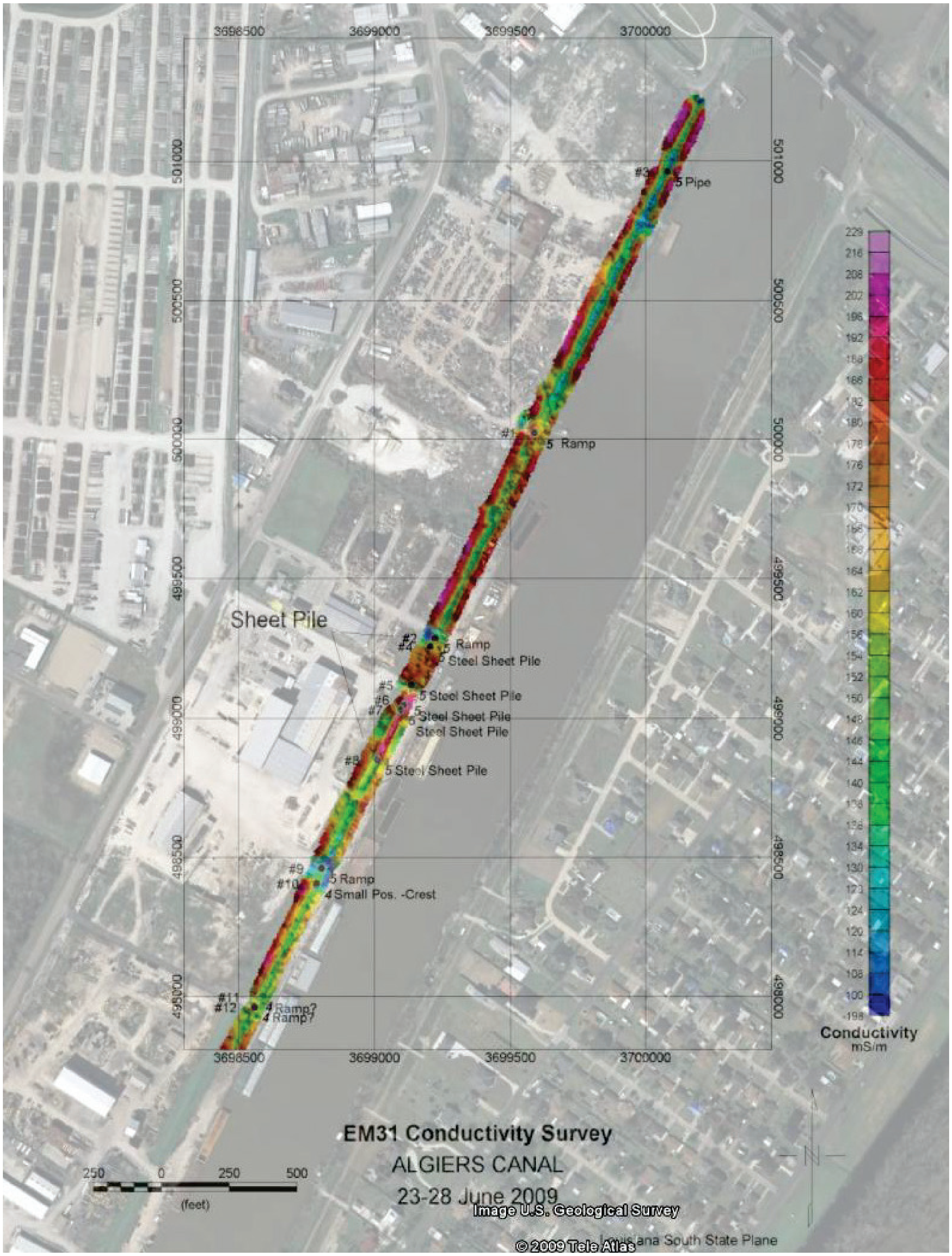


Figure 14. EM31 conductivity survey results overlaid on Google Earth image, Section 2.

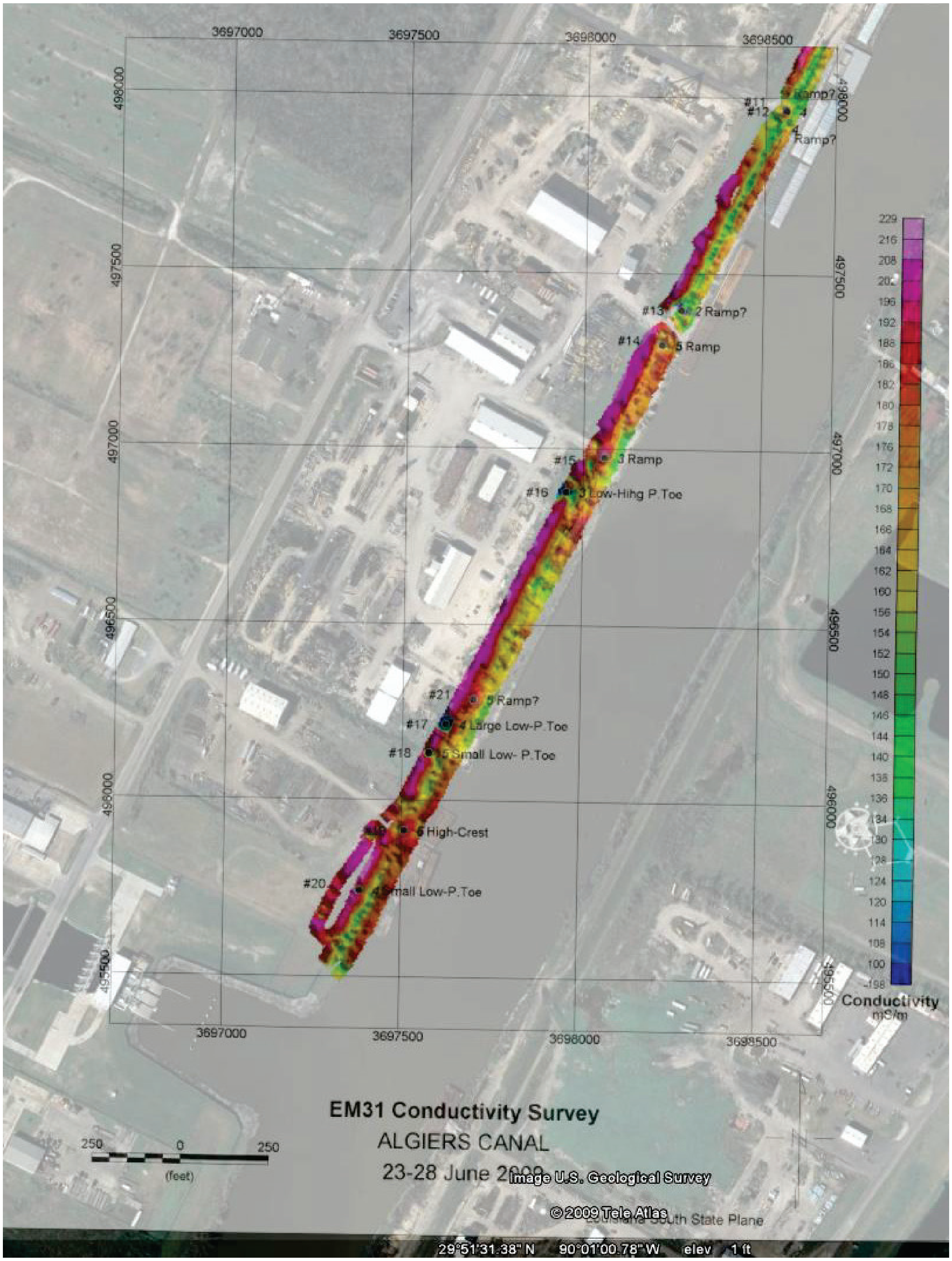


Figure 15. EM31 conductivity survey results overlaid on Google Earth image, Section 3.

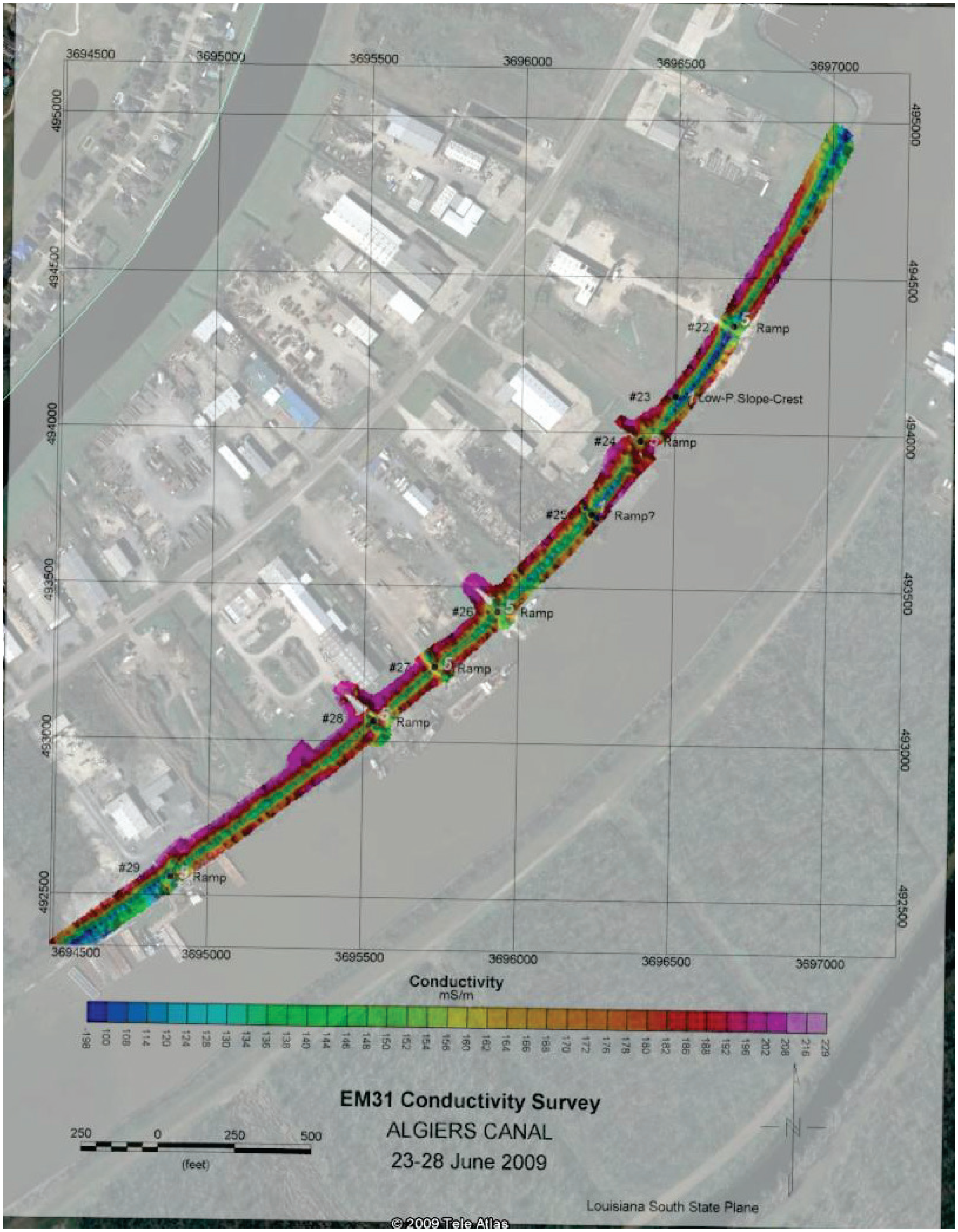
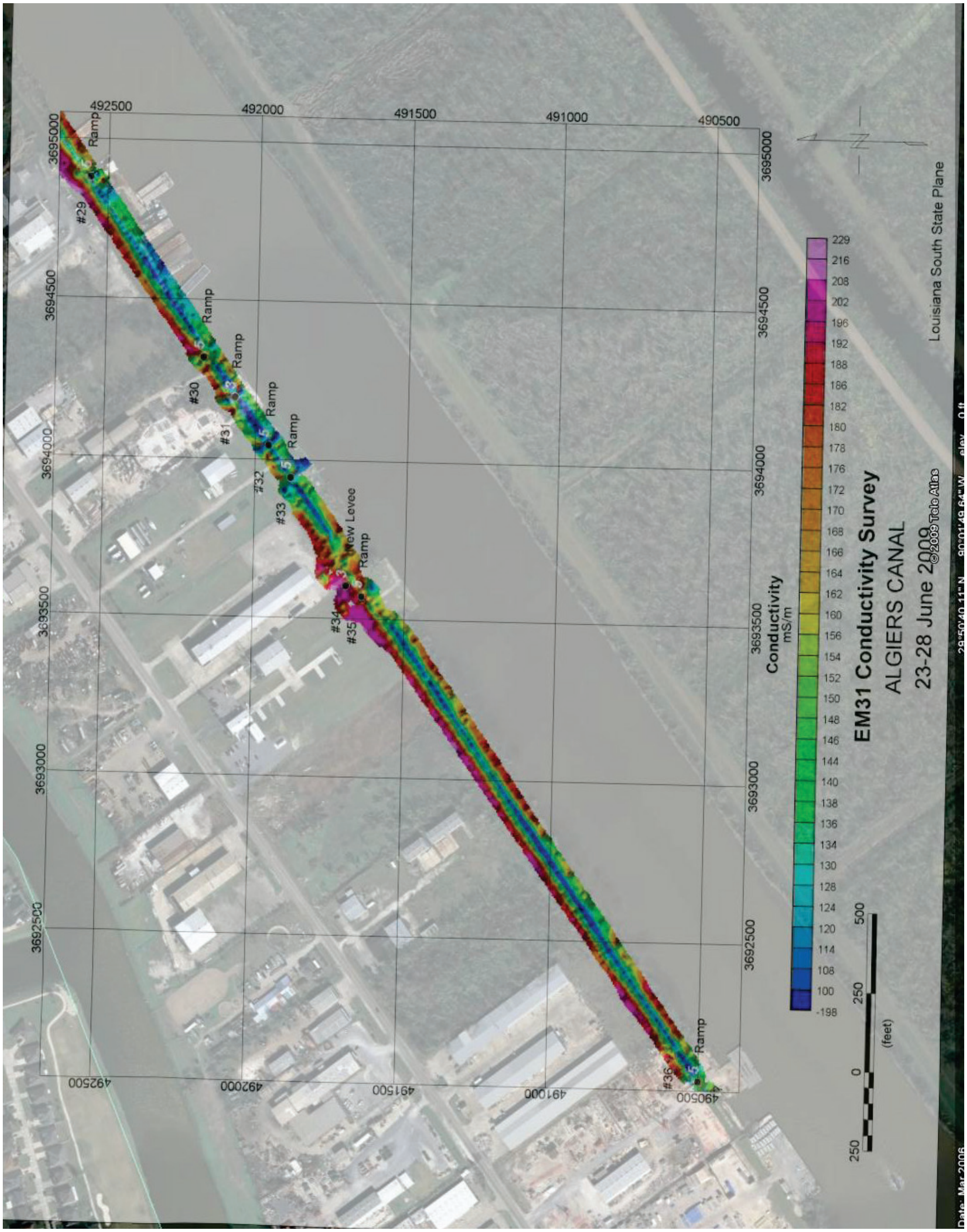


Figure 16. EM31 conductivity survey results overlaid on Google Earth image, Section 4.



3.2.5 Section 5

This section stretches between approximate stations 1116+53 and 1154+48 and has three priority 1 and one priority 2 anomalies as shown in Figure 17. The priority 1 anomaly located at station 1141+03, anomaly 41, indicates the possibility of an object crossing beneath the levee. Anomaly 42, a priority 2 anomaly, indicates an area of low conductivity values in the center line of the levee near station 1142+39. Anomaly 41 may be caused by a change in material type. Anomalies 44 and 45 (stations 1150+70 and 1150+86, respectively) are located approximately 25 ft southwest of an area marked with cable crossing signs. These are two priority 1 anomalies and are probably caused by the same item. No indications of a buried cable were noted over the marked area, which is also characterized by a noticeable hump in the levee. However, approximately 20 to 30 ft southwest of the marked cable crossing area, the instrument indicated a strong response to a buried metallic object oriented perpendicular to the axis of the levee. Anomaly 47, located near station 1154+79, is caused by a buried steel pipe that crosses the levee and is visible on the protected toe. However, it is not nearly as strong as an anomaly shown in the in-phase results.

3.2.6 Section 6

This section stretches between approximate stations 1154+48 and 1194+31 (Figure 18). All of the anomalies in this section have priority numbers of 5, with the exception of anomaly 52 that has a priority of 3. The location of anomaly 52, station 1187+50, coincides with the location of a ramp. However, there is an indication of a localized metallic object.

3.2.7 Section 7

Section 7 extends between approximate stations 1194+31 and 1211+26 (Figure 19). Four anomalies, one a priority 1 and the remaining three priority 5 anomalies, were interpreted for this section. Anomaly 55, a priority 1 anomaly, is located at station 1196+63, and is a strong linear-shaped anomaly that crosses the levee. There is a hump in the levee center line directly over the location of the anomaly. It is presumed that this anomaly is caused by a buried nitrogen line indicated in the construction drawings. The remaining anomalies coincide with the locations of ramps.

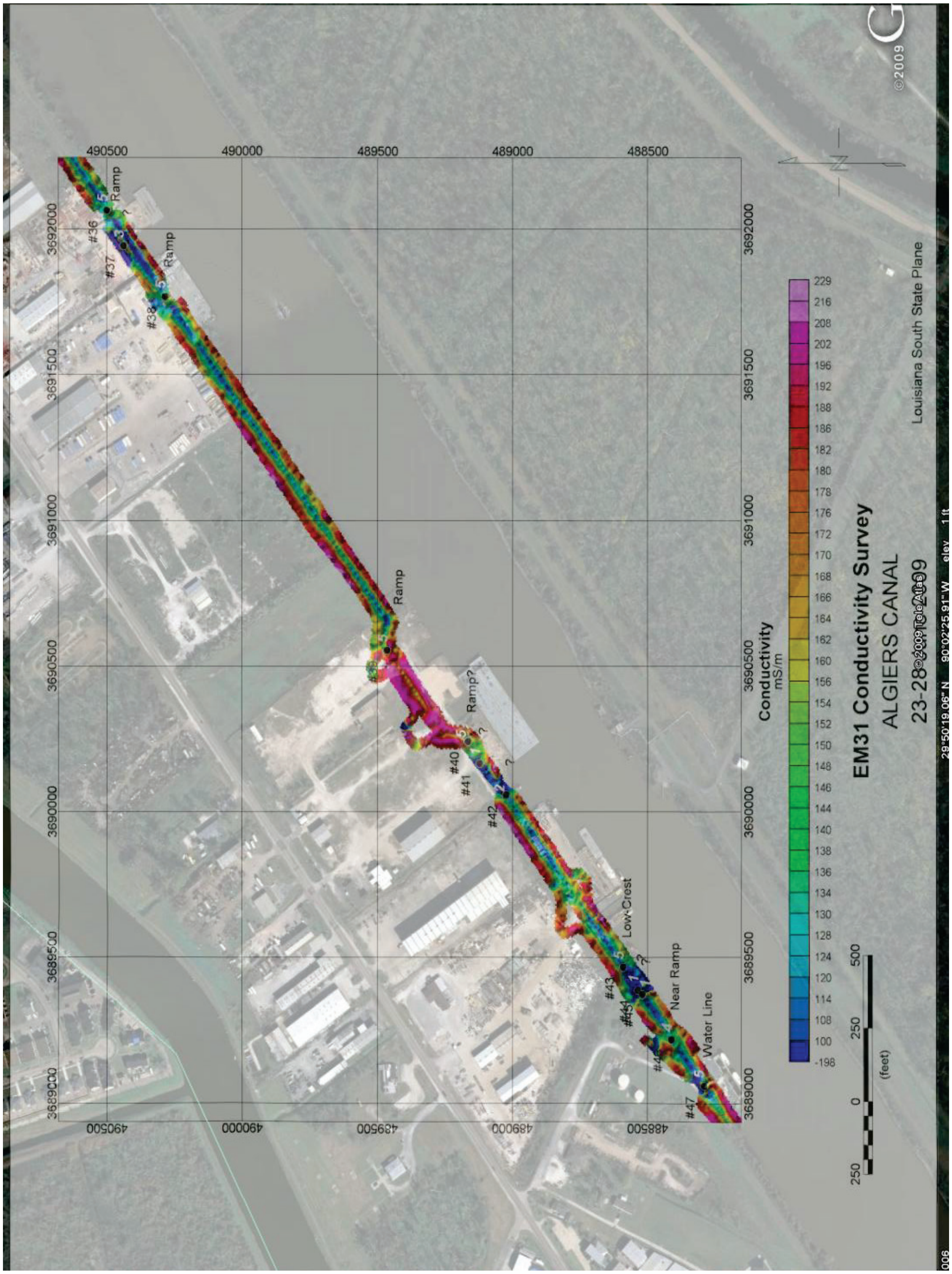


Figure 17. EM31 conductivity survey results overlaid on Google Earth image, Section 5.

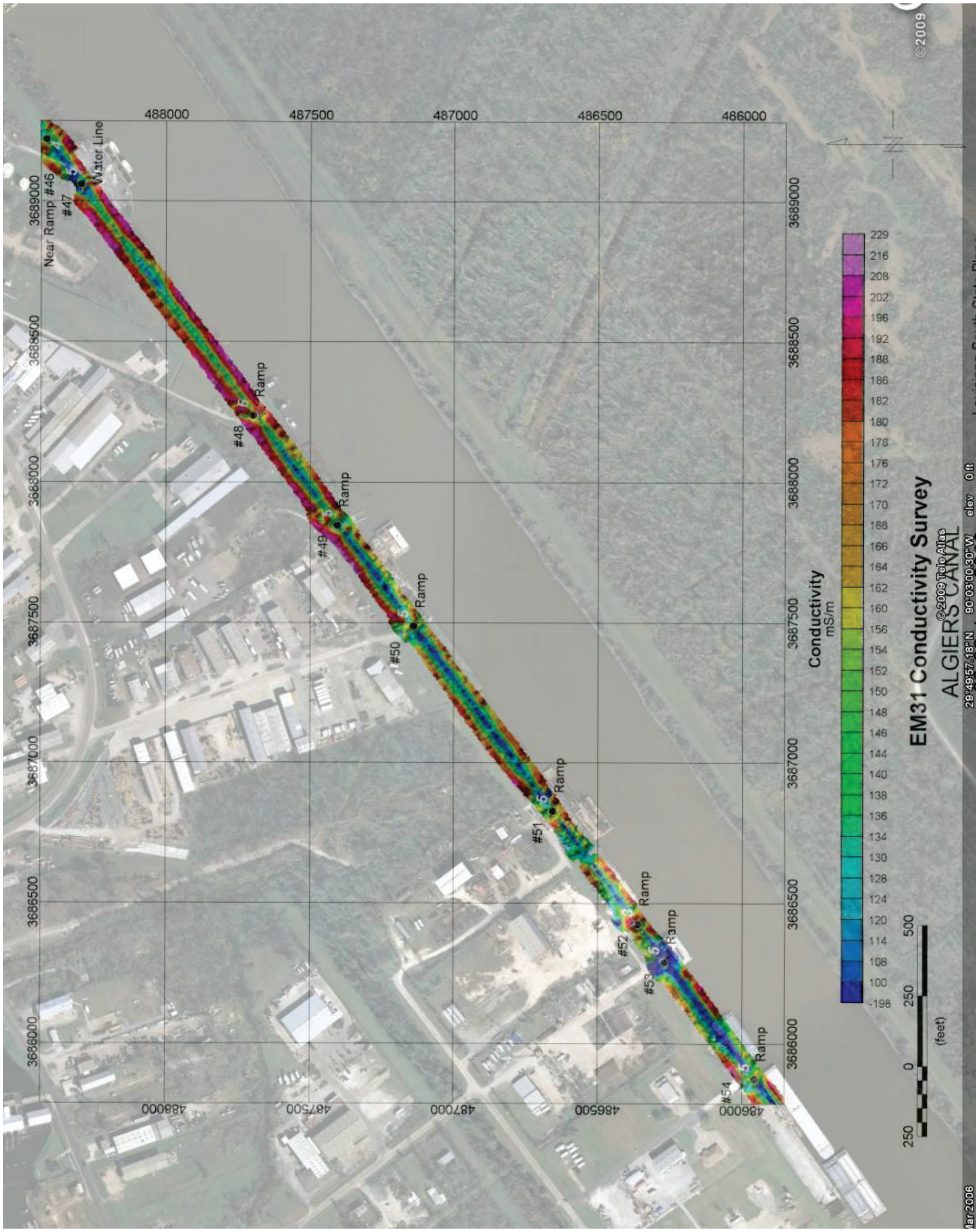
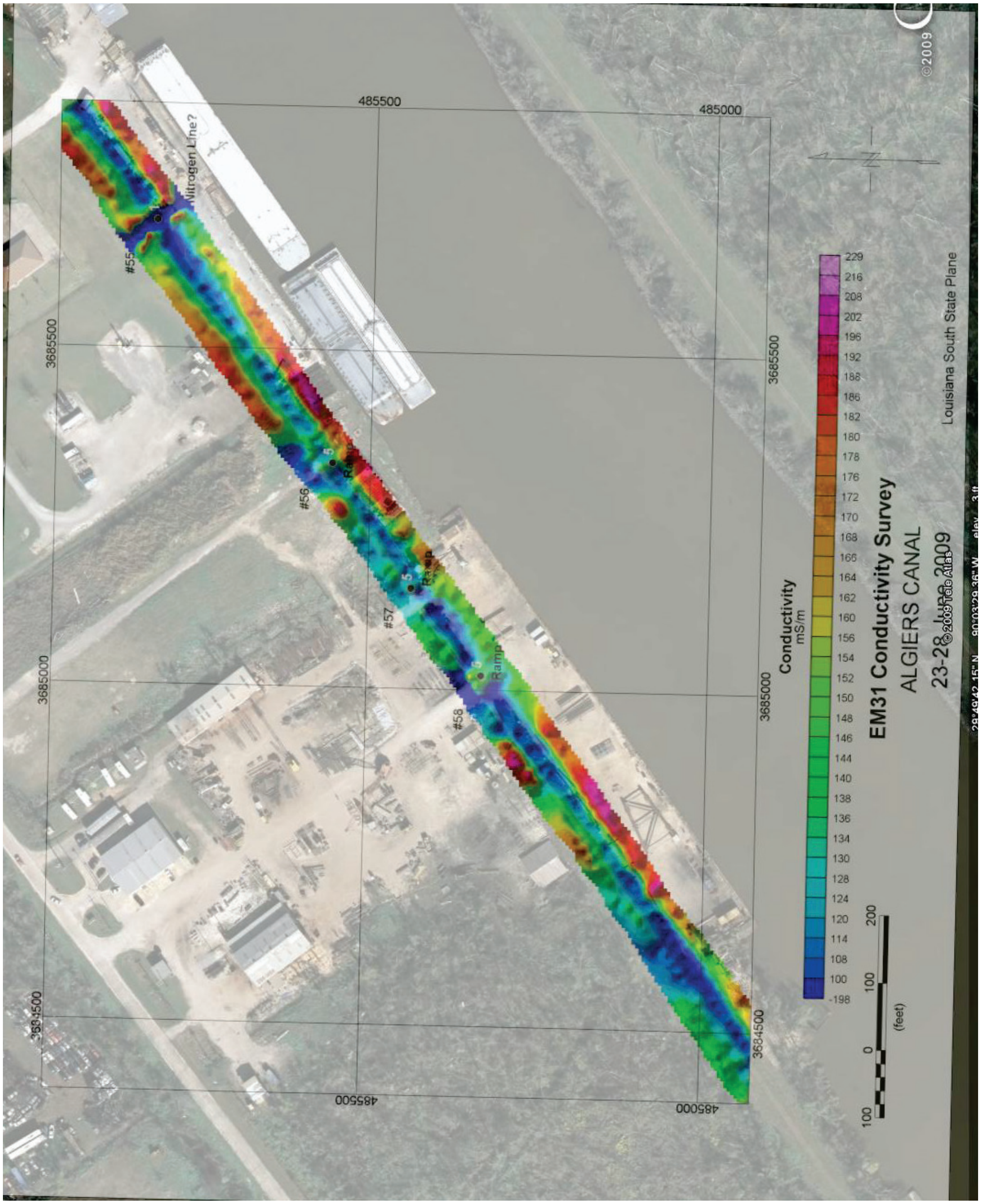


Figure 18. EM31 conductivity survey results overlaid on Google Earth image, Section 6.

Figure 19. EM31 conductivity survey results overlaid on Google Earth image, Section 7.



3.2.8 Section 8

The southernmost section extends between approximate stations 1211+76 and 1229+44 (Figure 20). Anomaly 59, a priority 2 anomaly, indicates the possibility of an object on or below the unprotected slope or a change in material. This section of levee had not been raised at the time this survey was conducted.

3.3 Combined in-phase and conductivity survey results

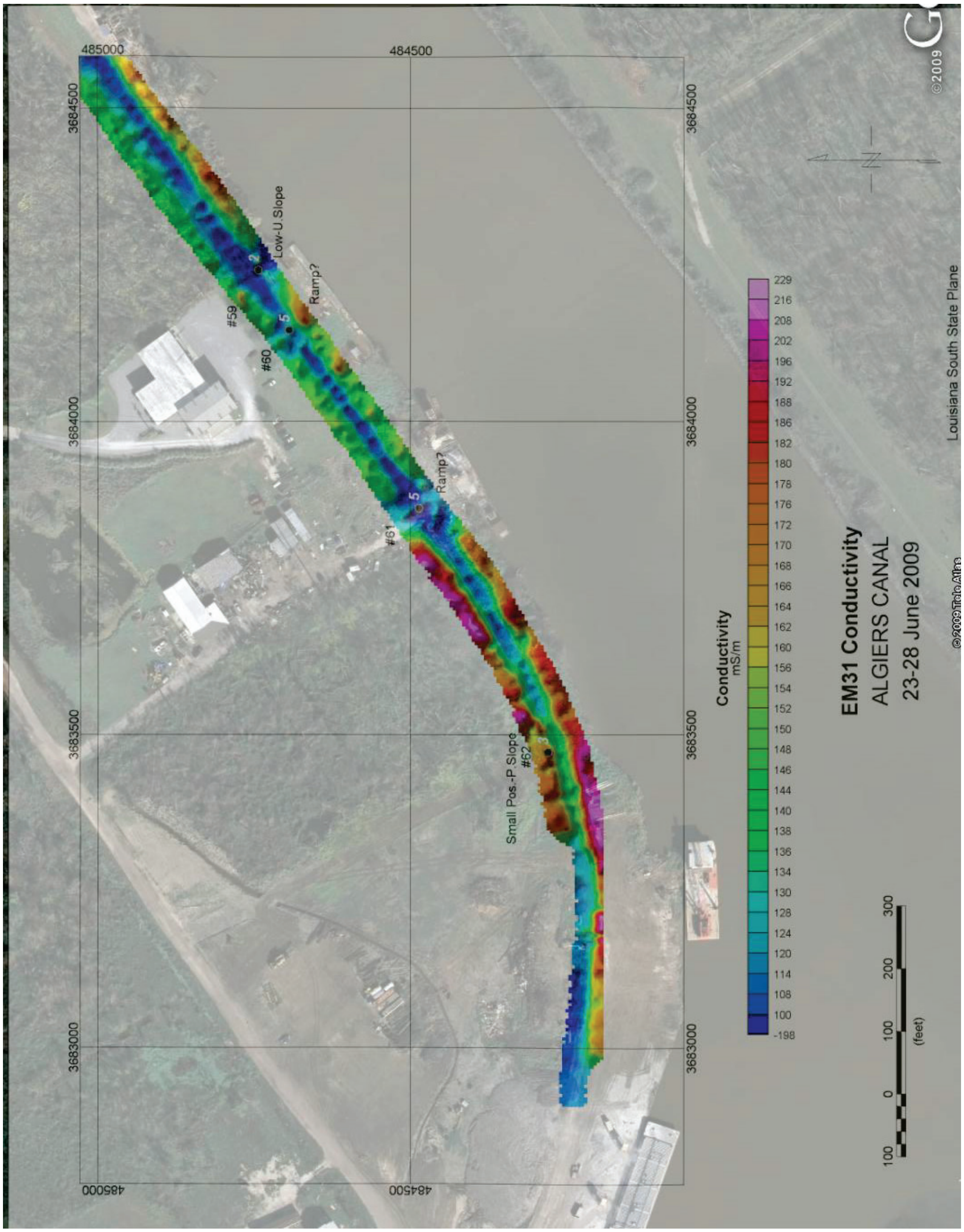
Many of the in-phase and conductivity anomalies correspond well. Table 1 presents the locations of the in-phase and conductivity priority 1 and 2 anomalies. In-phase and conductivity anomalies, which are considered to correspond to the same anomaly location, are shown on the same row.

Table 1. EM31 in-phase and conductivity survey priority 1 and 2 anomaly locations.

In-phase Anomaly No.	In-phase Anomaly Station	In-phase Anomaly Priority[a]	Conductivity Anomaly No.	Conductivity Anomaly Station	Conductivity Anomaly Priority[a]
11	1022+90	2	13	1023+02	2
24	1060+01	1	23	1060+04	1
28	1064+65	1	25	1064+65	1
31	1116+53	2	-	-	-
34	1141+21	1	41	1141+03	1
35	1141+46	2	-	-	-
36	1142+06	2	42	1142+39	2
37	1150+86	1	44	1150+70	1
48	1196+64	1	55	1196+63	1
-	-	-	59	1214+66	2
52	1224+86	1	-	-	-
53	1224+28	2	-	-	-
54	1224+70	1	-	-	-
55	1225+25	2	-	-	-
56	1226+77	2	-	-	-

[a] Note: 1 = Highest priority.
2 = Lowest priority.

Figure 20. EM31 conductivity survey results overlaid on Google Earth image, Section 8.



4 Conclusions and Recommendations

A geophysical study was performed to locate buried debris within the levees on the west side of Algiers Canal approximately 8 miles south-southwest of downtown New Orleans. The levees are located adjacent to industrial and metal fabricating businesses. An EM induction survey was conducted along the crest, slopes, and toes of the levee to locate anomalous conditions indicative of buried material. EM31 anomalies, presumed to be the location of buried debris, were mapped and their coordinates tabulated for further interrogation.

It is recommended that anomalies with priorities of 1 and 2 should be considered for further investigation. The investigation should consist of (a) reoccupying the anomaly locations and visually looking for potential sources that could cause a conductivity or in-phase anomaly such as surface metallic objects, changes in soil type, or any type other feature that indicates that there is a buried object, (b) resurveying with an EM instrument or magnetometer anomalous areas that have no visual explanation for causing an anomaly to more accurately define the extent of the anomaly, and (c) perform intrusive exploration. It is suggested that during excavation operations that an EM and/or magnetic instrument be onsite to ensure that the correct object(s) are removed.

References

Geonics. 1980. *Electromagnetic terrain conductivity measurements at low induction numbers*. Technical Note TN-6. Mississauga, Ontario, Canada:Geonics Limited.

Llopis, J., and J. Simms. 2014. *Geophysical surveys for locating buried utilities, Lake Pontchartrain levees, New Orleans, LA*. ERDC/GSL TR-14-23. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Appendix A: EM31 In-phase Survey Anomaly Maps

Figure A1. EM31 in-phase survey results, Section 1.

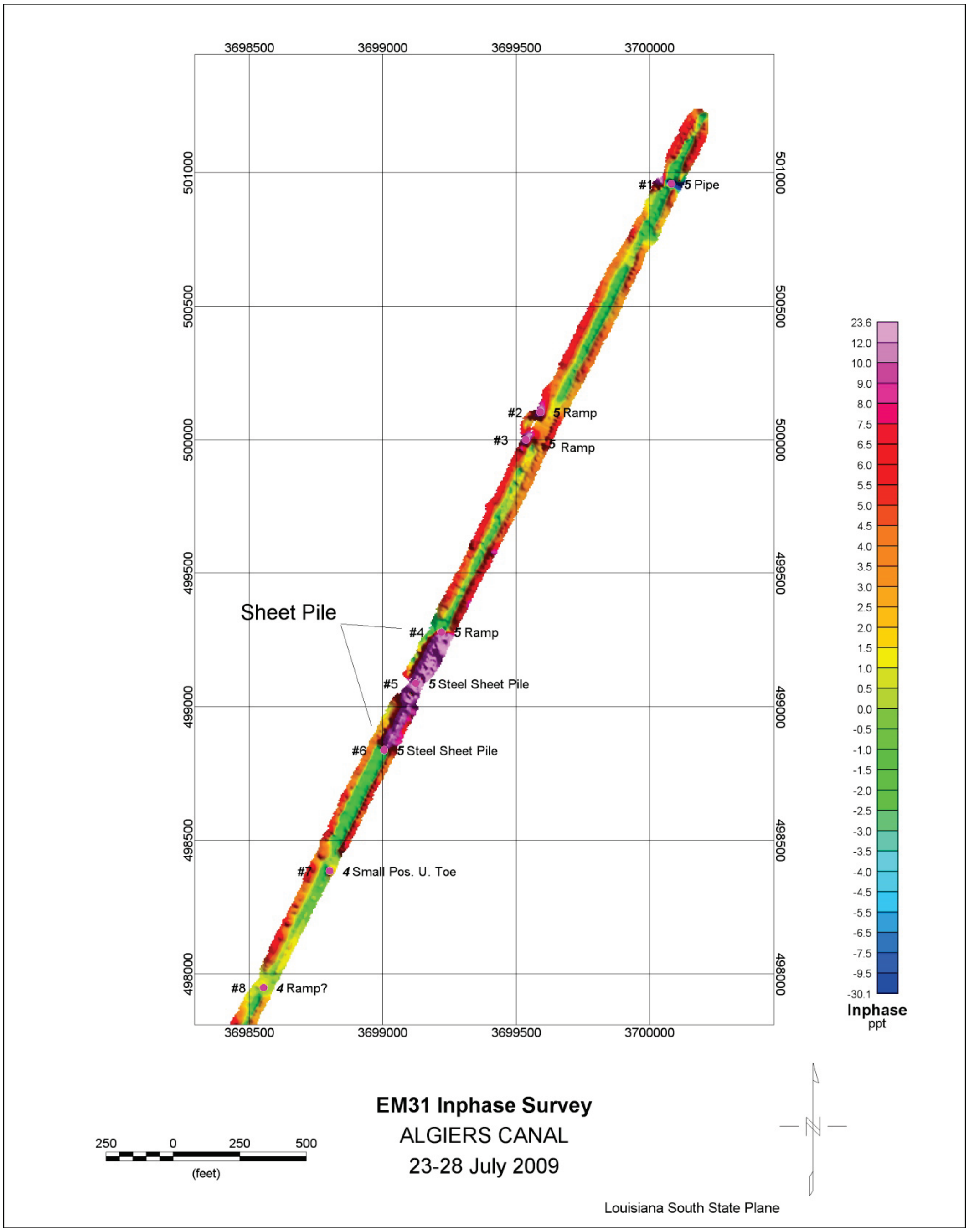


Figure A2. EM31 in-phase survey results, Section 2.

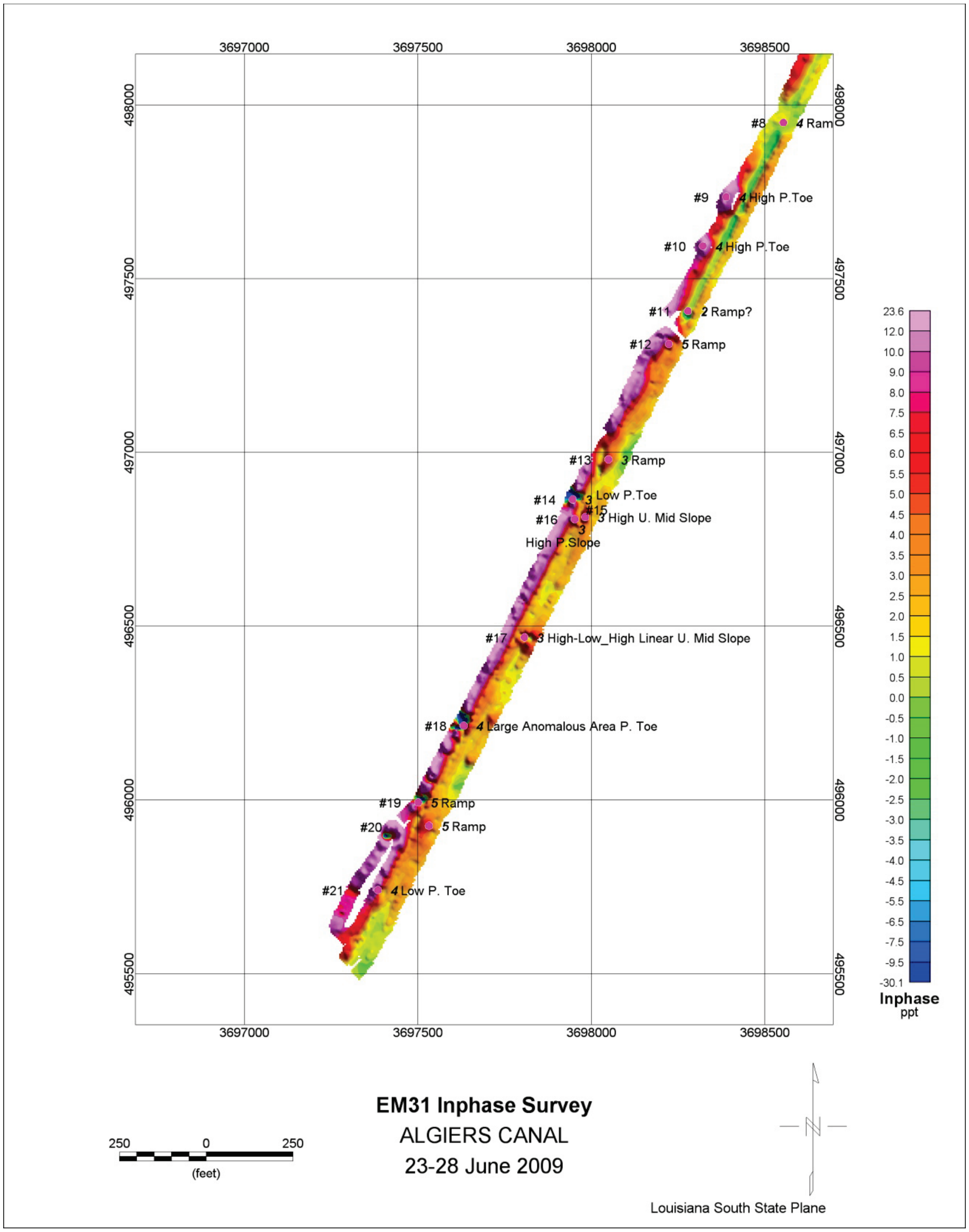


Figure A3. EM31 in-phase survey results, Section 3.

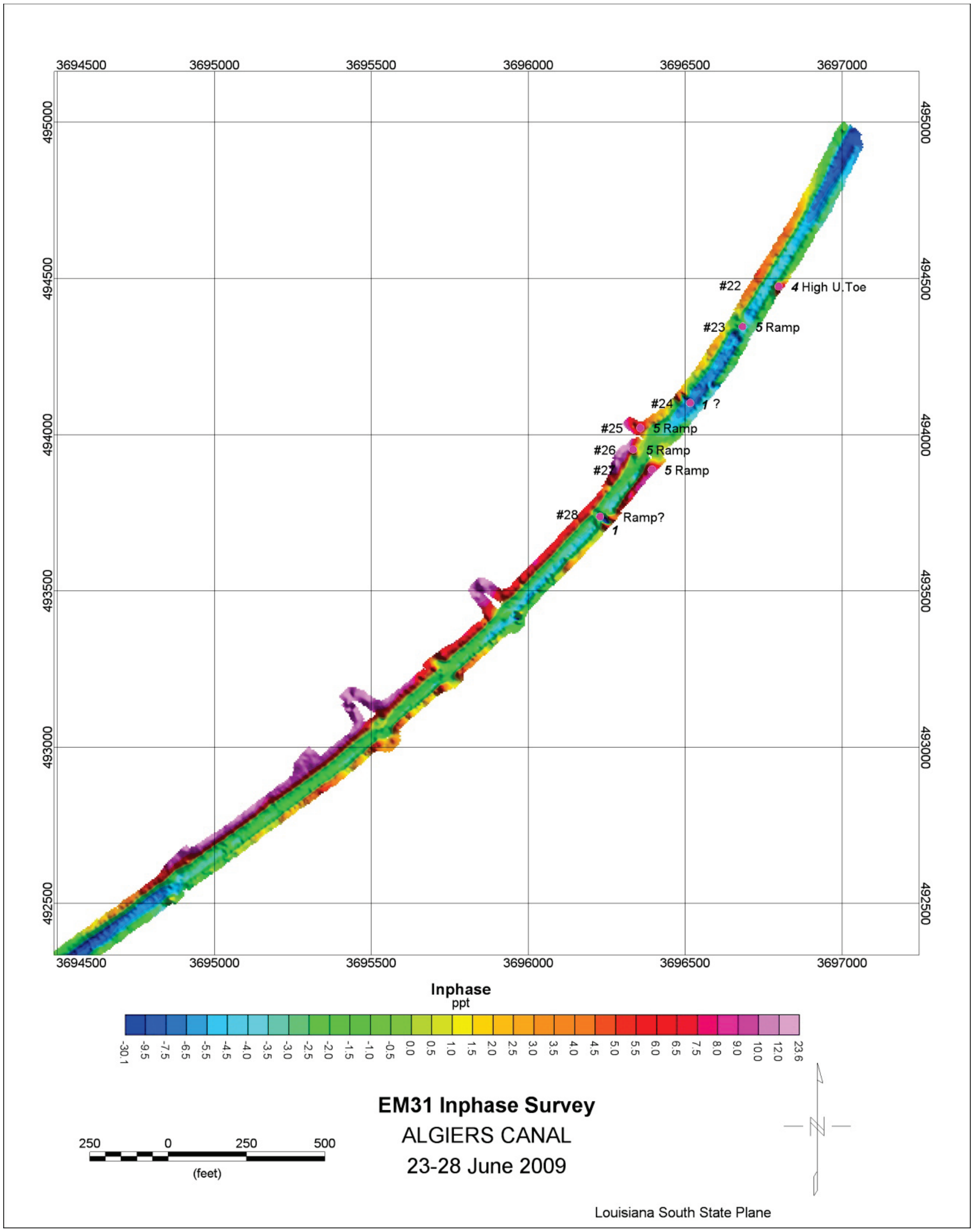


Figure A4. EM31 in-phase survey results, Section 4.

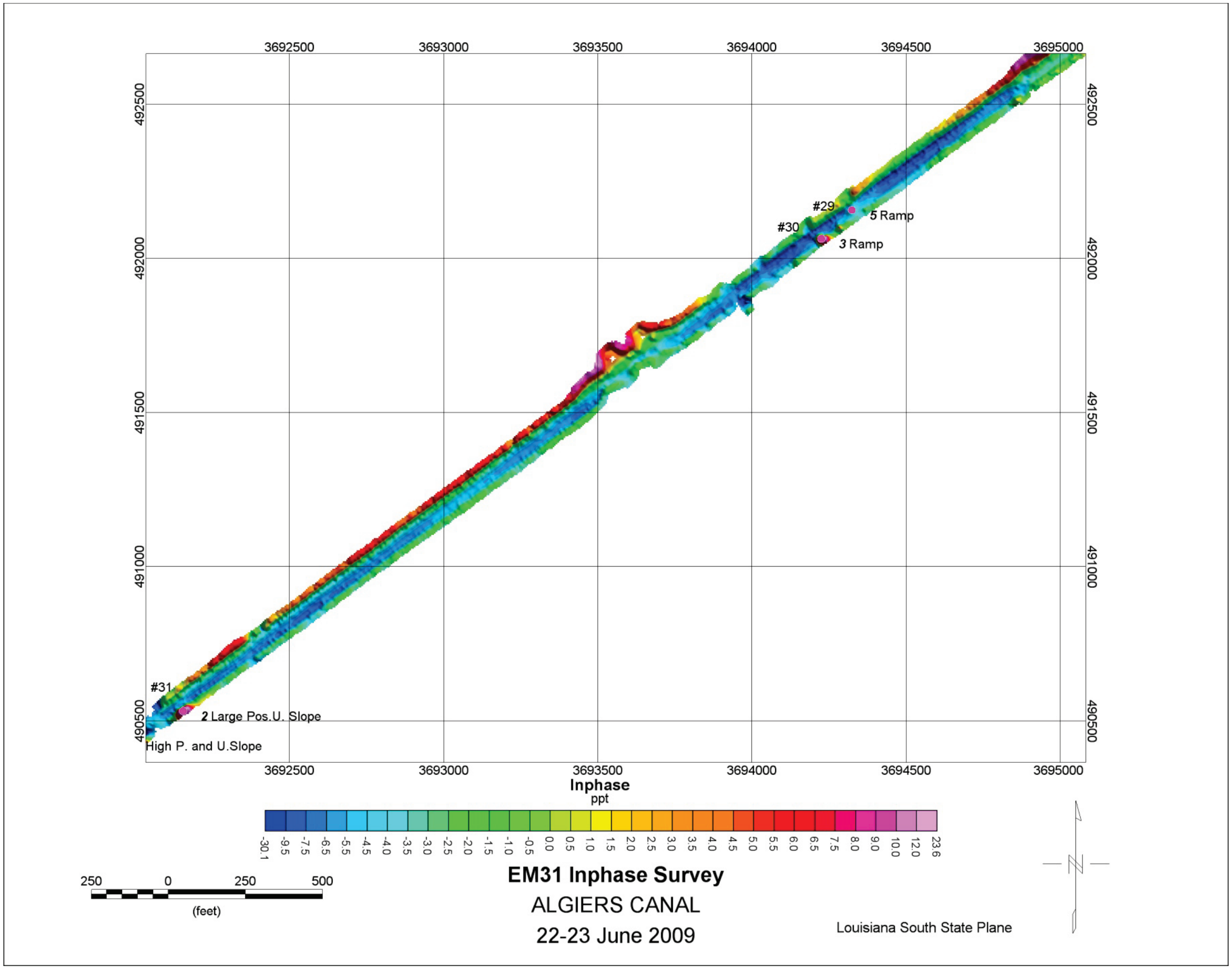


Figure A5. EM31 in-phase survey results, Section 5.

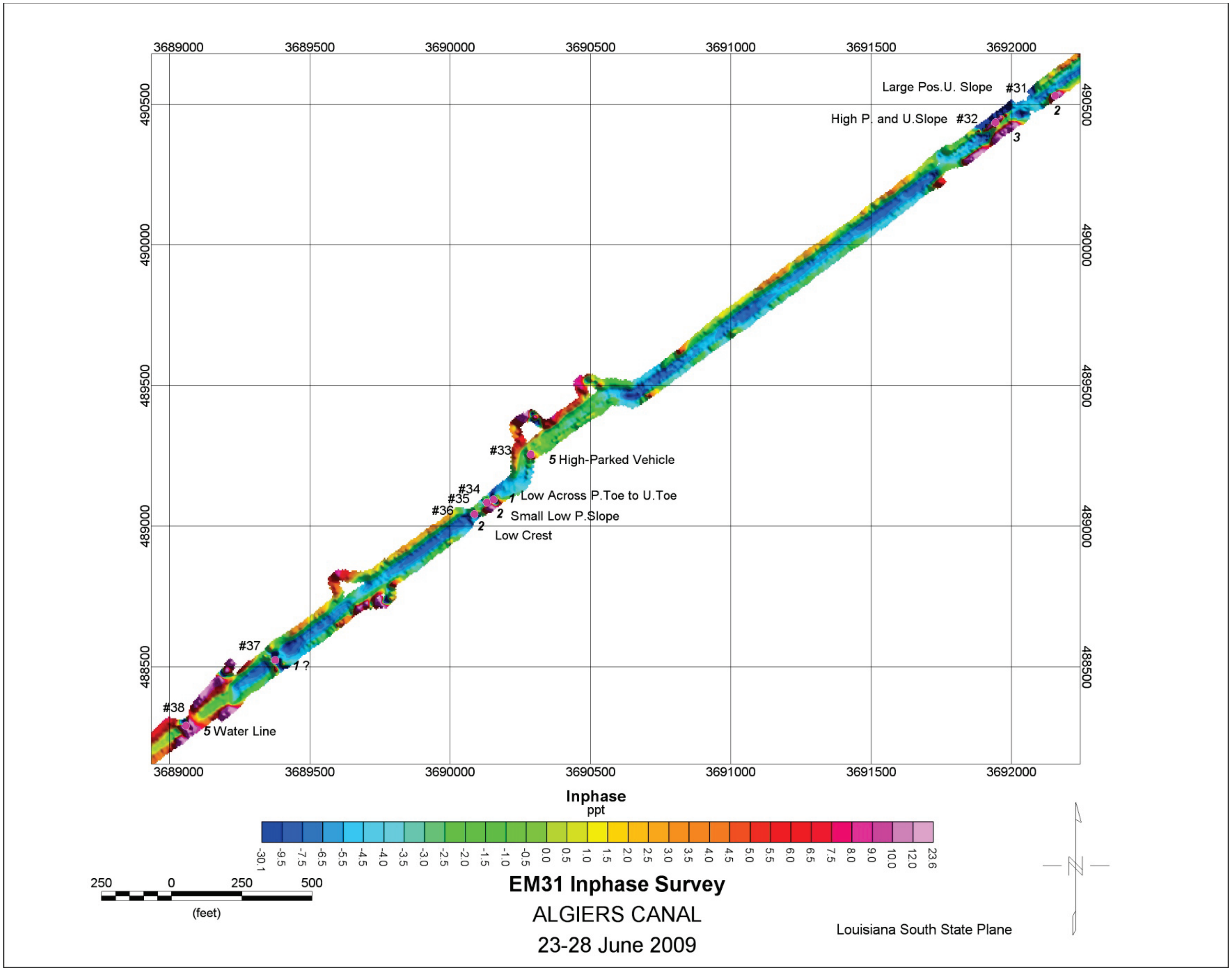


Figure A6. EM31 in-phase survey results, Section 6.

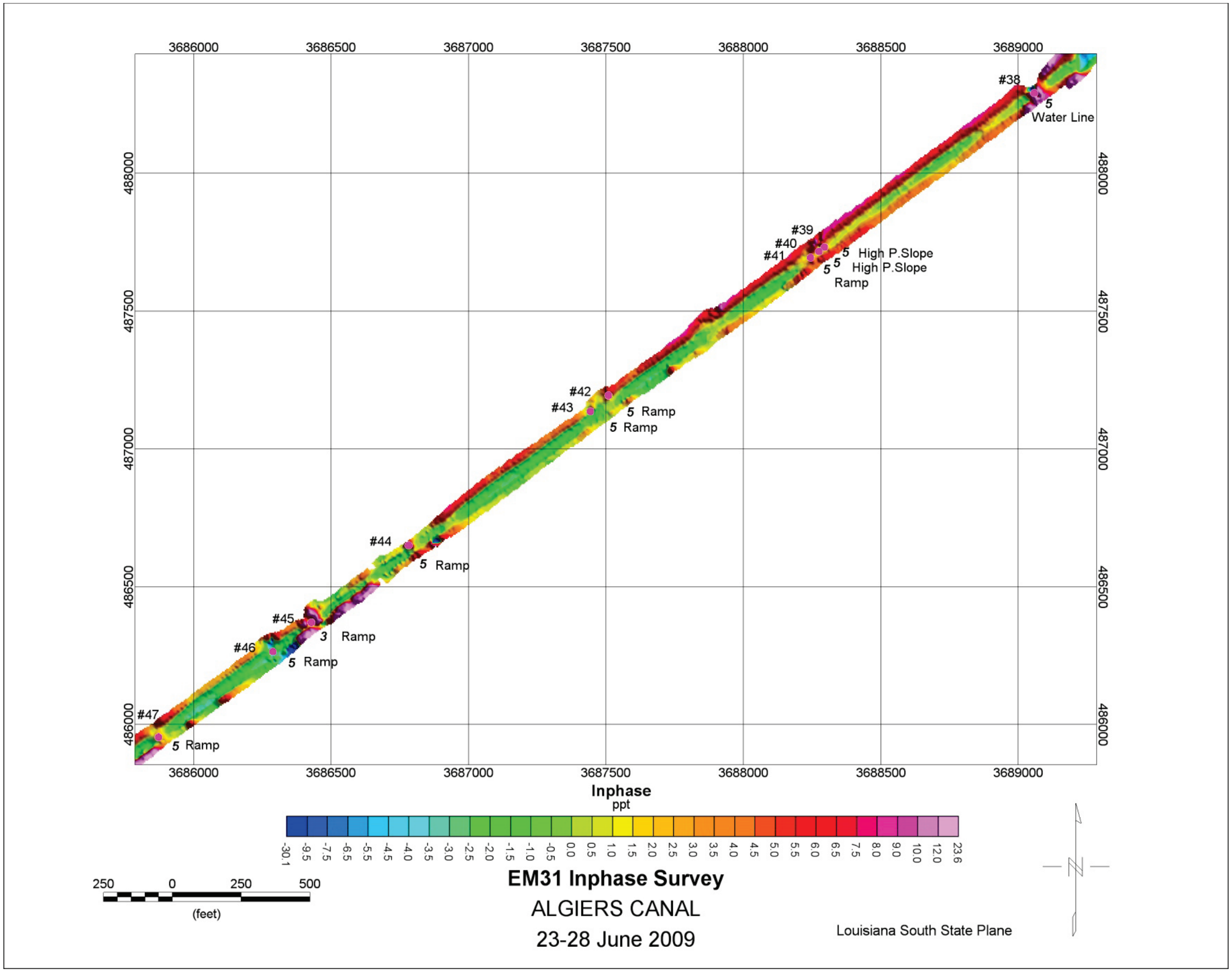


Figure A7. EM31 in-phase survey results, Section 7.

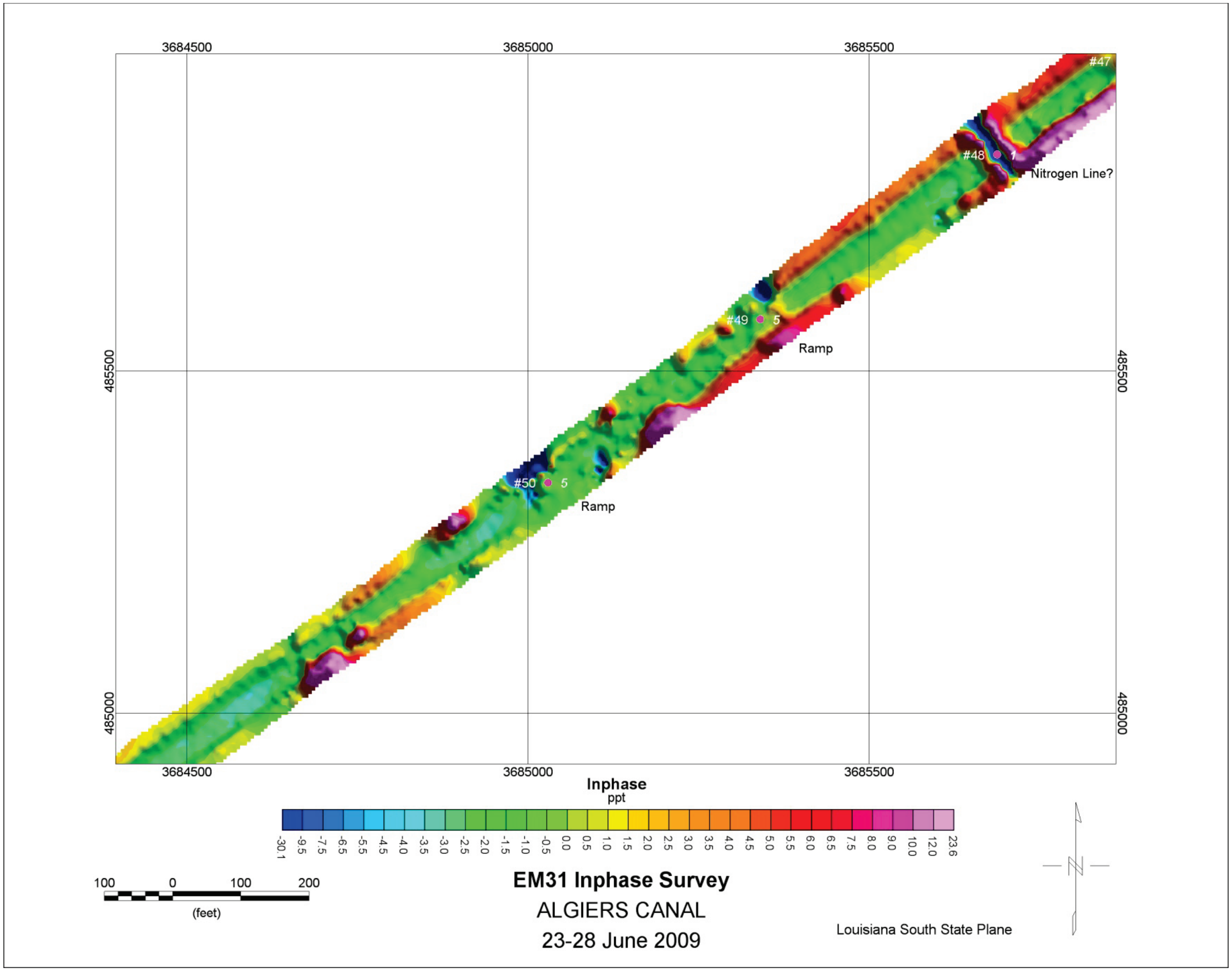
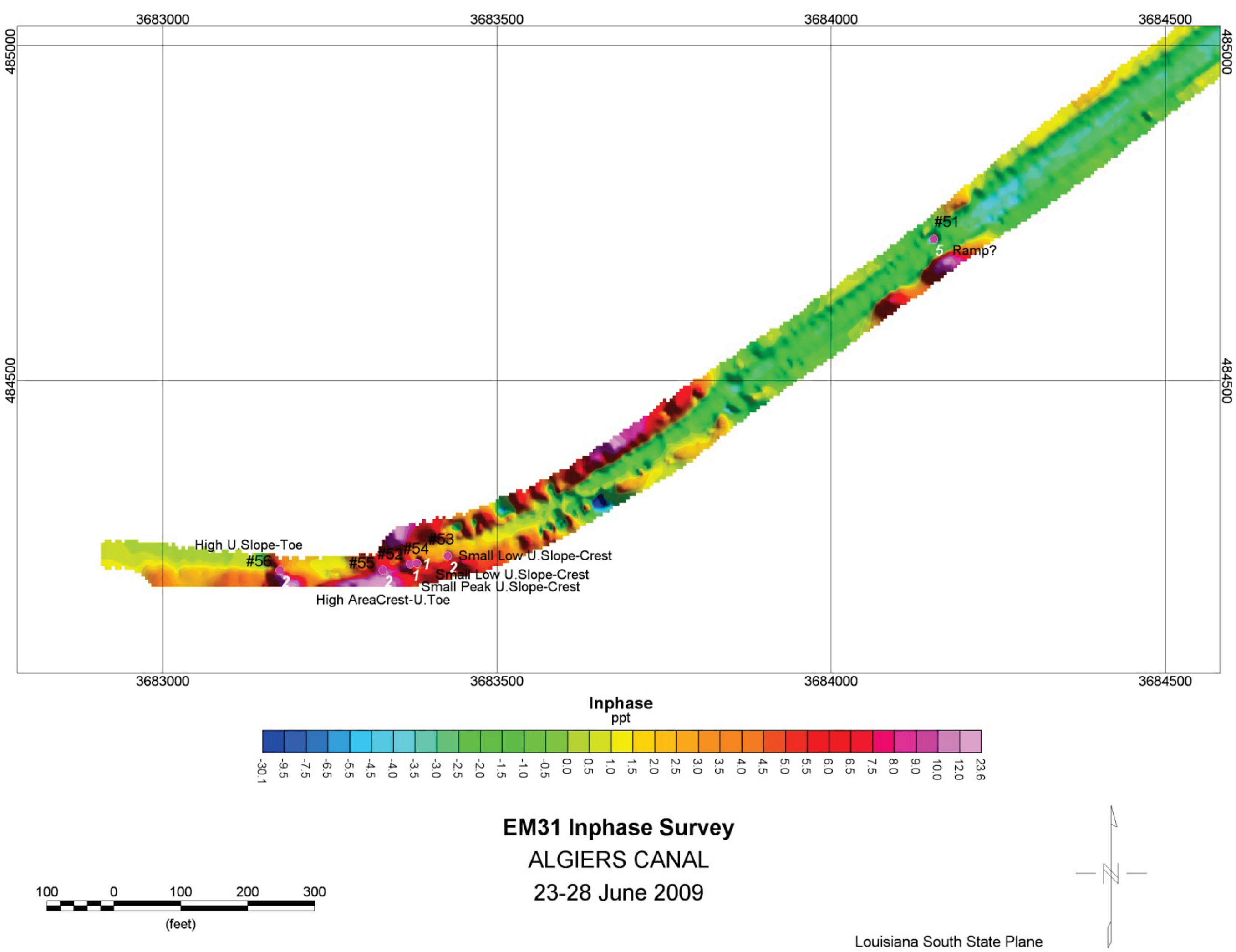


Figure A8. EM31 in-phase survey results, Section 8.



Appendix B: EM31 Conductivity Survey Anomaly Maps

Figure B1. EM31 conductivity survey results, Section 1.

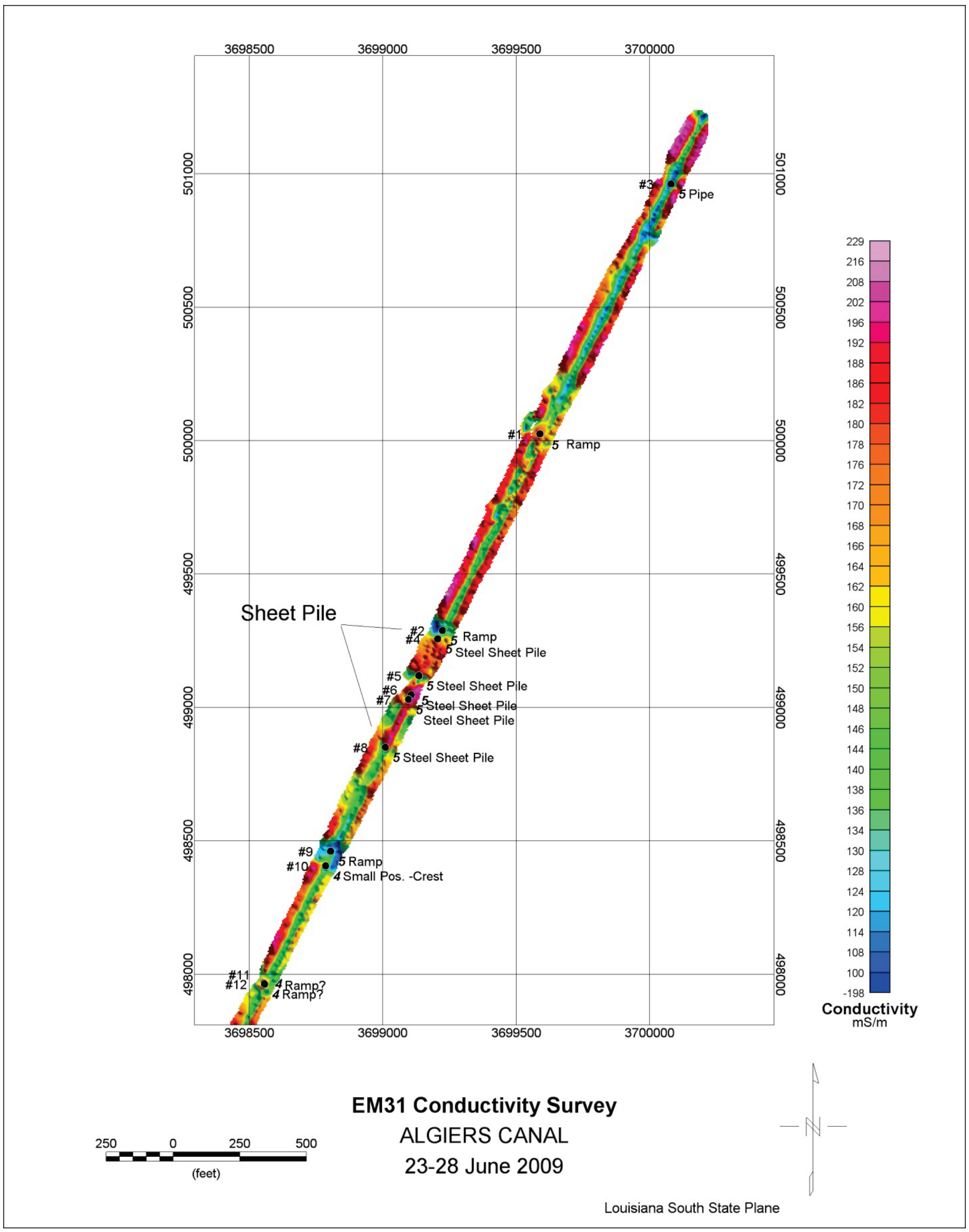


Figure B2. EM31 conductivity survey results, Section 2.

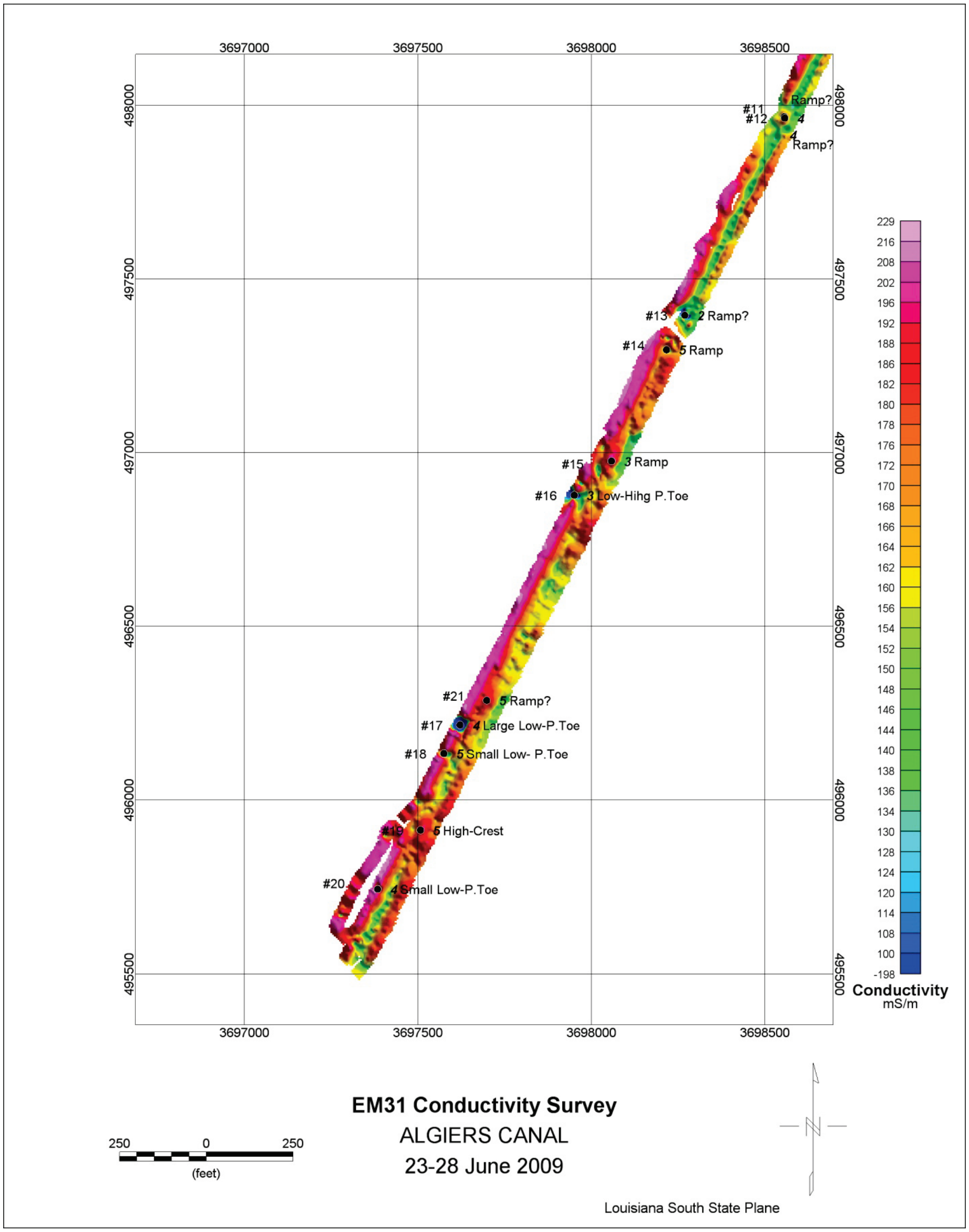


Figure B3. EM31 conductivity survey results, Section 3.

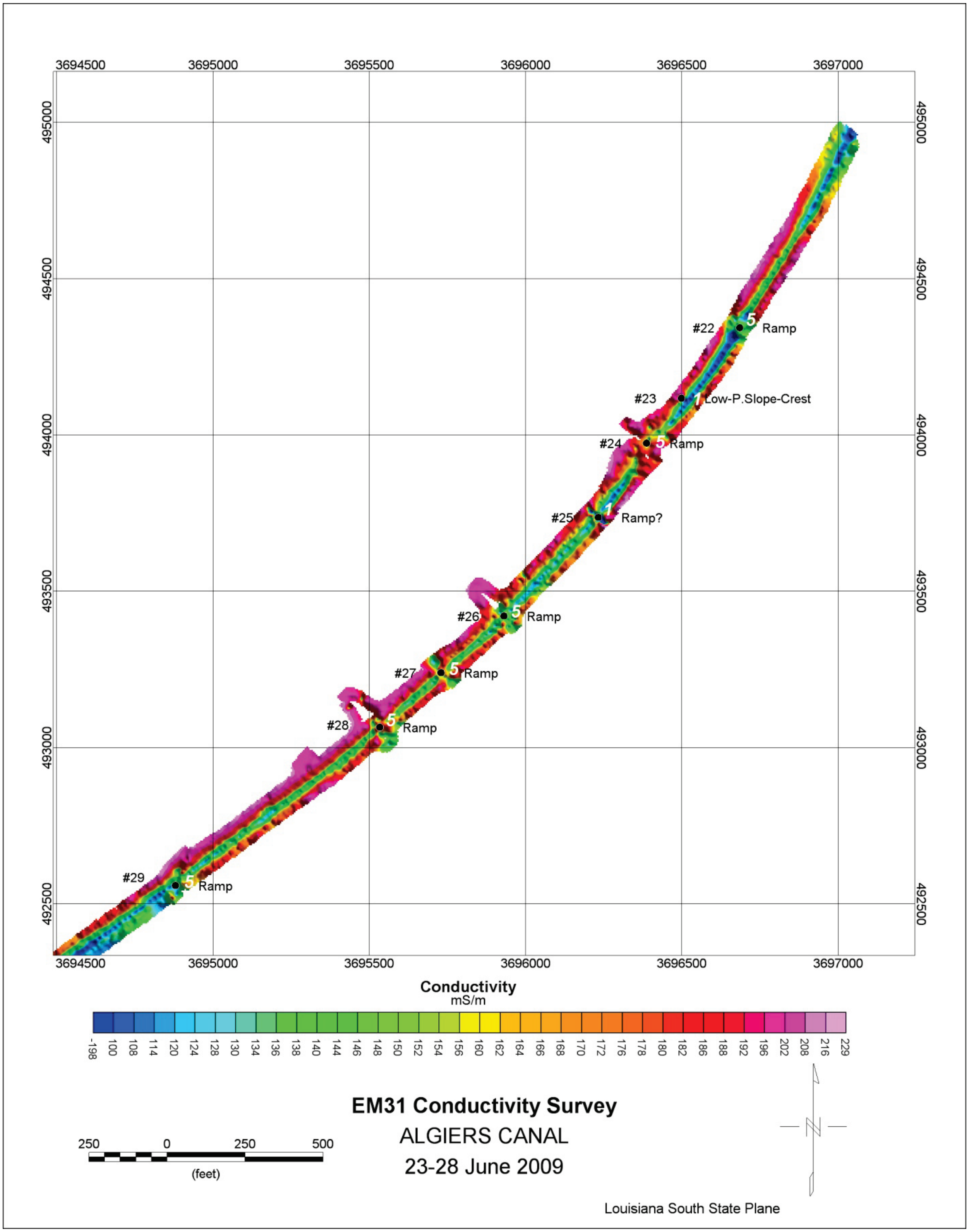


Figure B4. EM31 conductivity survey results, Section 4.

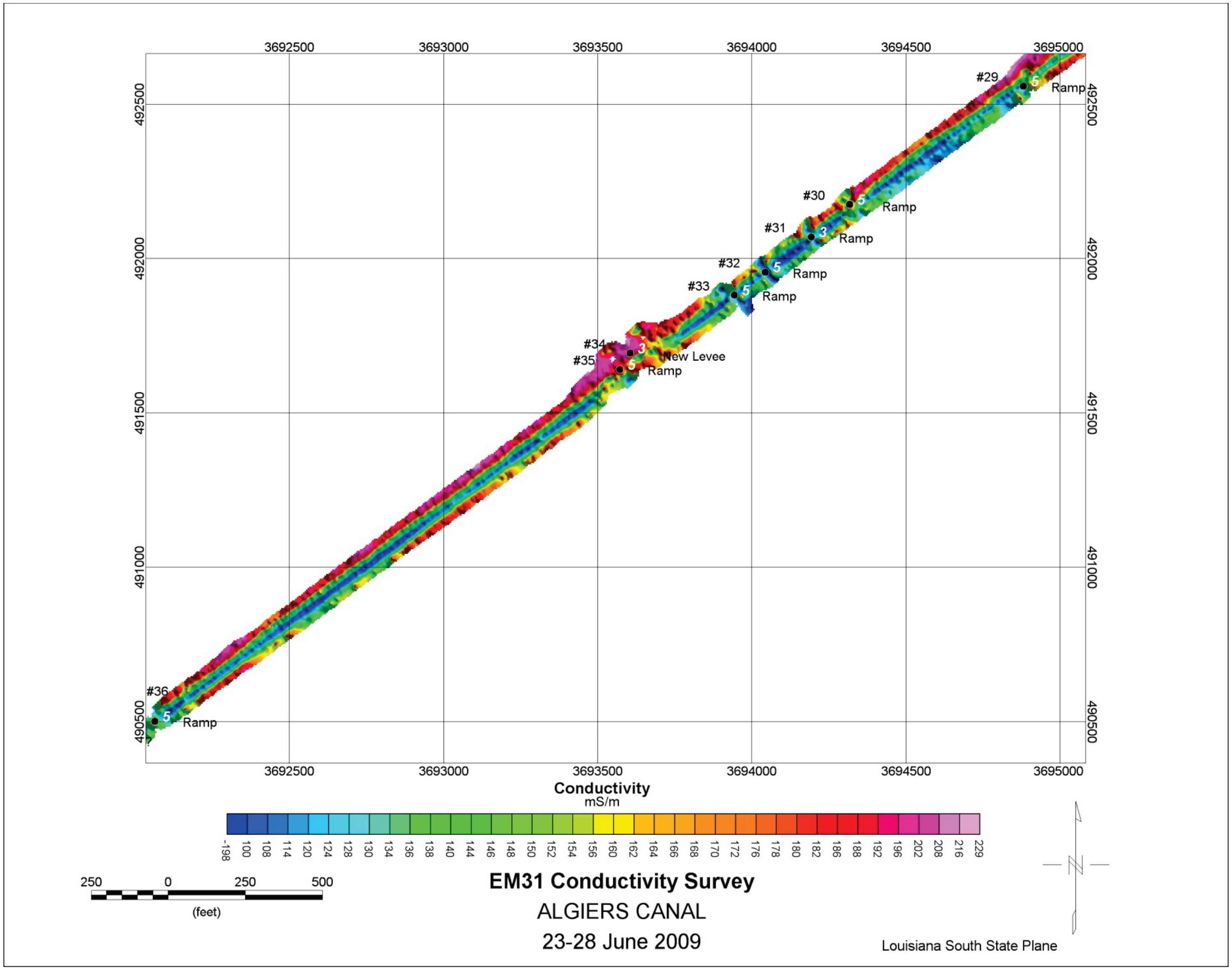


Figure B5. EM31 conductivity survey results, Section 5.

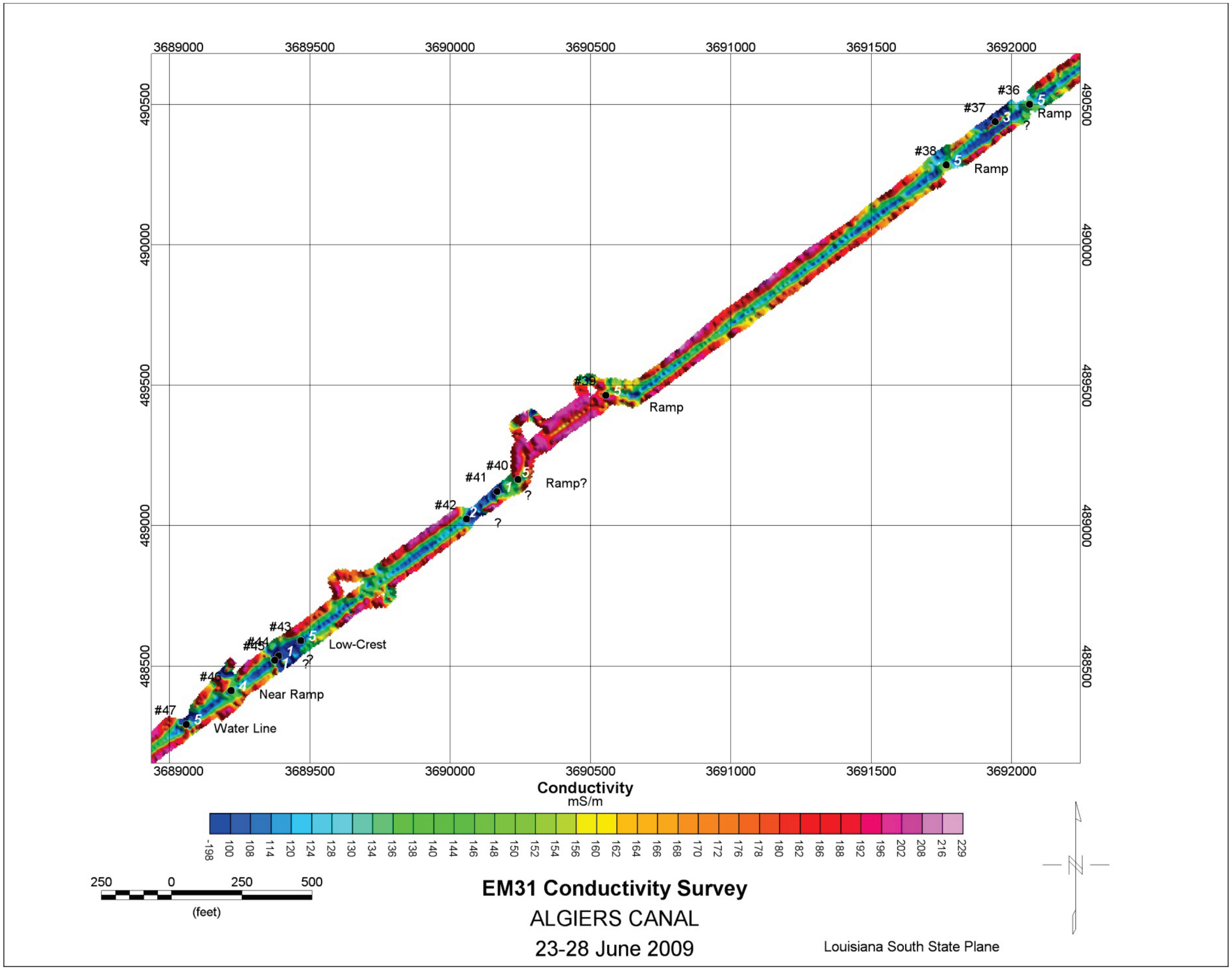


Figure B6. EM31 conductivity survey results, Section 6.

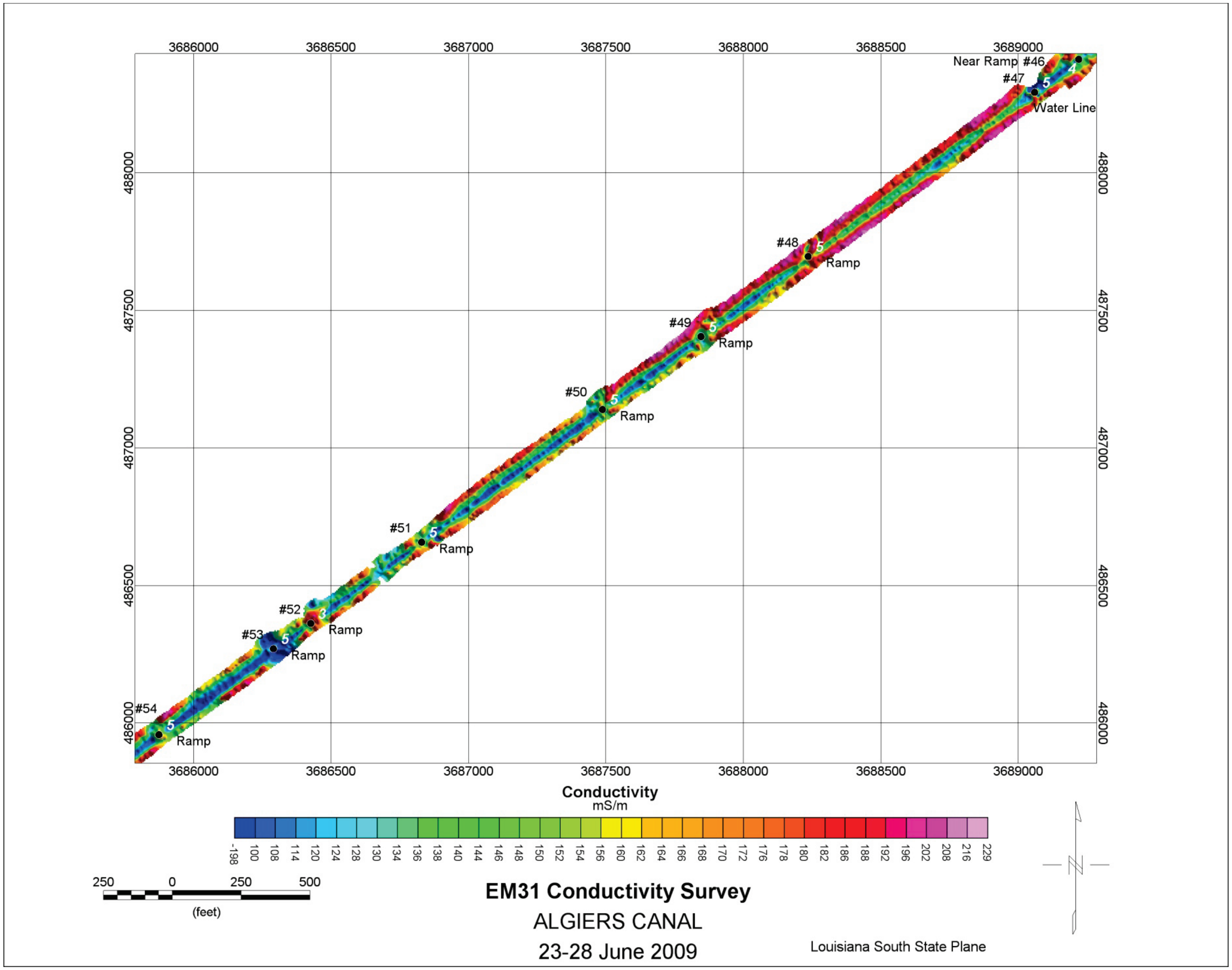


Figure B7. EM31 conductivity survey results, Section 7.

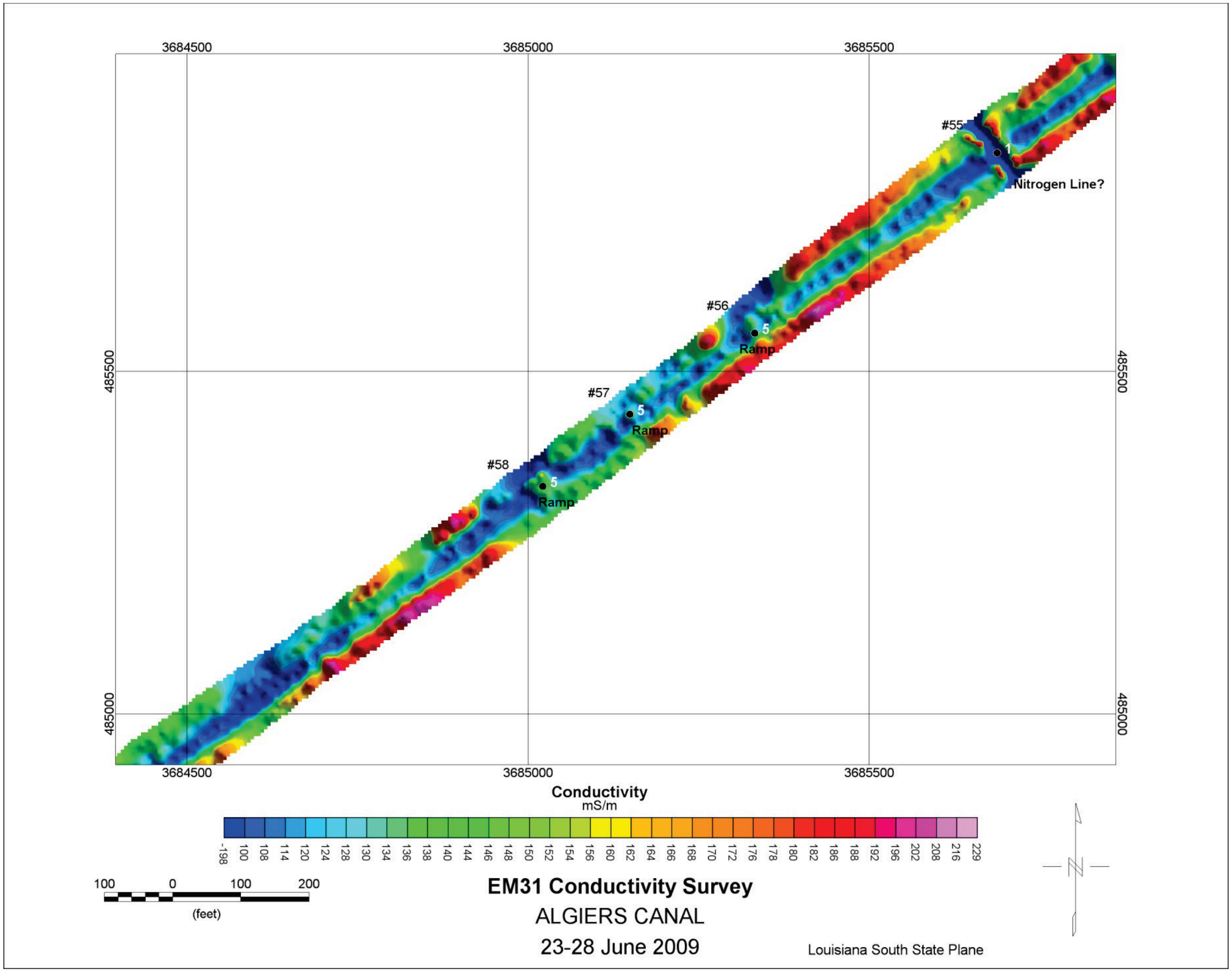
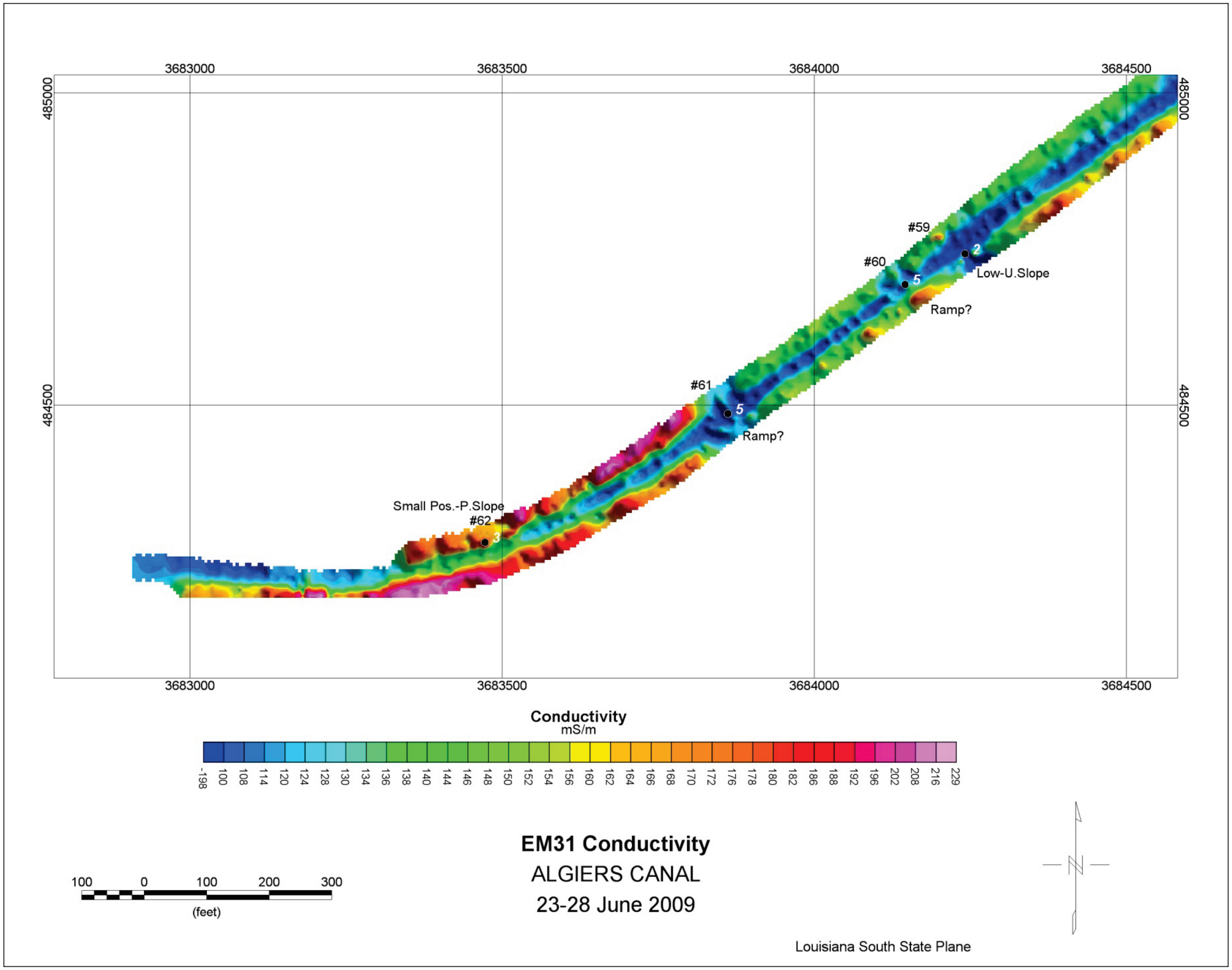


Figure B8. EM31 conductivity survey results, Section 8.



Appendix C: Tabulated Coordinates of Interpreted Anomalies, EM31 In-phase Survey

Table C1. EM31 in-phase survey interpreted anomaly locations.

Anomaly No.	LA South State Plane		Geographic		Station	Priority[a]	Description
	X, US ft	Y, US ft	Longitude	Latitude			
1	3700081	500958	90.01051268	29.87088332	982+90	5	Pipe
2	3699590	500104	90.01209282	29.86855067	992+90	5	Ramp
3	3699536	500000	90.01226697	29.86826642	994+06	5	Ramp
4	3699220	499280	90.01329007	29.86629667	1001+81	5	Ramp
5	3699123	499088	90.01360307	29.8657718	1004+14	5	Steel Sheet Pile
6	3699005	498838	90.01398441	29.86508812	1006+78	5	Steel Sheet Pile
7	3698801	498386	90.01464439	29.86385172	1011+85	4	Small Pos. U. Toe
8	3698553	497949	90.01544262	29.86265796	1016+79	4	Ramp?
9	3698388	497735	90.01597091	29.86207474	1019+56	4	High P.Toe
10	3698321	497594	90.01618738	29.86168916	1021+04	4	High P.Toe
11	3698278	497407	90.01632981	29.86117633	1022+90	2	Ramp?
12	3698223	497312	90.01650676	29.86091685	1024+03	5	Ramp
13	3698049	496980	90.0170677	29.86000945	1027+74	3	Ramp
14	3697946	496865	90.01739679	29.85969649	1029+16	3	Low P.Toe
15	3697982	496814	90.01728507	29.85955512	1029+48	3	High U. Midslope
16	3697952	496808	90.01737993	29.85953957	1029+72	3	High P.Slope
17	3697807	496468	90.01784966	29.85860925	1033+38	3	High-Low_High Linear U. Midslope
18	3697632	496214	90.0184109	29.85791636	1036+46	4	Large Anomalous Area P. Toe
19	3697501	495993	90.01883214	29.85731281	1038+94	5	Ramp
20	3697532	495926	90.01873678	29.85712761	1039+49	5	Ramp
21	3697385	495741	90.01920718	29.85662355	1041+83	4	Low P. Toe
22	3696798	494475	90.02110461	29.85316095	1055+35	4	High U.Toe
23	3696683	494346	90.02147202	29.85280986	1057+05	5	Ramp
24	3696516	494102	90.02200761	29.8521442	1060+01	1	?
25	3696357	494022	90.02251204	29.85192923	1061+56	5	Ramp
26	3696334	493953	90.02258708	29.85174022	1062+36	5	Ramp

Anomaly No.	LA South State Plane		Geographic		Station	Priority[a]	Description
	X, US ft	Y, US ft	Longitude	Latitude			
27	3696394	493889	90.02240013	29.85156235	1062+36	5	Ramp
28	3696229	493738	90.02292604	29.85115234	1064+65	1	Ramp?
29	3694324	492157	90.0289918	29.84686485	1089+47	5	Ramp
30	3694225	492064	90.02930741	29.84661223	1090+80	3	Ramp
31	3692155	490532	90.03589129	29.84246432	1116+53	2	Large Pos.U. Slope
32	3691942	490436	90.03656653	29.84220698	1118+92	3	High P. and U.Slope
33	3690287	489256	90.04182843	29.83901374	1139+19	5	High-Parked Vehicle
34	3690154	489095	90.04225362	29.83857516	1141+21	1	Low Across P.Toe to U.Toe
35	3690130	489085	90.04232967	29.83854841	1141+46	2	Small Low P.Slope
36	3690086	489043	90.04246994	29.83843429	1142+06	2	Low Crest
37	3689376	488524	90.04472764	29.83702917	1150+86	1	?
38	3689058	488291	90.04573883	29.83639832	1154+48	5	Water Line
39	3688295	487732	90.04816501	29.8348848	1164+26	5	High P.Slope
40	3688275	487716	90.04822865	29.83484142	1164+52	5	High P.Slope
41	3688244	487694	90.04832719	29.83478188	1164+90	5	Ramp
42	3687509	487194	90.0506629	29.83342968	1173+74	5	Ramp
43	3687443	487136	90.0508731	29.83327223	1174+67	5	Ramp
44	3686782	486650	90.05297487	29.8319562	1182+81	5	Ramp
45	3686428	486370	90.05410115	29.83119716	1187+37	3	Ramp
46	3686288	486264	90.0545464	29.83090998	1189+12	5	Ramp
47	3685872	485954	90.05586923	29.83007034	1194+31	5	Ramp
48	3685687	485817	90.05645748	29.8296993	1196+64	1	Nitrogen Line?
49	3685340	485576	90.05756026	29.82904725	1200+87	5	Ramp
50	3685029	485337	90.05854943	29.82839959	1204+80	5	Ramp
51	3684153	484711	90.06133391	29.82670504	1215+54	5	Ramp?
52	3683370	484226	90.0638201	29.82539532	1224+86	1	Small Peak U.Slope-Crest
53	3683426	484238	90.06364308	29.82542661	1224+28	2	Small Low U.Slope-Crest

Anomaly No.	LA South State Plane		Geographic		Station	Priority[a]	Description
	X, US ft	Y, US ft	Longitude	Latitude			
54	3683380	484227	90.06378853	29.82539776	1224+70	1	Small Low U.Slope-Crest
55	3683329	484217	90.06394971	29.82537182	1225+25	2	High AreaCrest-U.Toe
56	3683175	484217	90.06443535	29.82537651	1226+77	2	High U.Slope-Toe

[a] Note: 1 = Highest priority.
5 = Lowest priority.

Appendix D: Tabulated Coordinates of Interpreted Anomalies, EM31 Conductivity Survey

Table D1. EM31 conductivity survey interpreted anomaly locations.

Anomaly No.	LA South State Plane		Geographic		Station	Priority*	Description
	X, US ft	Y, US ft	Longitude	Latitude			
1	3699589	500025.2	90.01209997	29.86833398	993+48	5	Ramp
2	3699223	499288.3	90.01327892	29.86631929	1001+82	5	Ramp
3	3700080	500961.9	90.01051498	29.87089401	982+90	5	Pipe
4	3699206	499256.7	90.01333577	29.86623297	1002+18	5	Steel Sheet Pile
5	3699135	499119.1	90.01356357	29.86585704	1003+72	5	Steel Sheet Pile
6	3699106	499047.6	90.01365705	29.8656612	1004+47	5	Steel Sheet Pile
7	3699096	499029.9	90.01368994	29.86561298	1004+67	5	Steel Sheet Pile
8	3699010	498850.6	90.0139691	29.86512256	1006+67	5	Steel Sheet Pile
9	3698804	498461.2	90.01463113	29.86405844	101+05	5	Ramp
10	3698786	498406.4	90.01469175	29.86390827	1011+62	4	Small Pos. -Crest
11	3698555	497966.8	90.01543473	29.86270696	1016+62	4	Ramp?
12	3698557	497963	90.01543035	29.8626963	1016+68	4	Ramp?
13	3698269	497395.6	90.01635917	29.8611453	1023+02	2	Ramp?
14	3698216	497296.5	90.01652911	29.86087438	1024+15	5	Ramp
15	3698058	496975.9	90.01703976	29.85999783	1027+70	3	Ramp
16	3697950	496877.8	90.01738265	29.85973155	1028+96	3	Low-High P.Toe
17	3697621	496216.6	90.01844457	29.85792375	1036+45	4	Large Low-P.Toe
18	3697575	496134.3	90.01859392	29.85769903	1037+39	5	Small Low- P.Toe
19	3697507	495913.9	90.01881481	29.85709509	1039+70	5	High-Crest
20	3697384	495744.1	90.01921018	29.85663211	1041+78	4	Small Low-P.Toe
21	3697698	496287.2	90.01819915	29.85811561	1035+56	5	Ramp?

Anomaly No.	LA South State Plane		Geographic		Station	Priority*	Description
	X, US ft	Y, US ft	Longitude	Latitude			
22	3696685	494343	90.02146555	29.85280158	1057+10	5	Ramp
23	3696499	494117.5	90.02206225	29.85218738	1060+04	1	Low-P.Slope-Crest
24	3696387	493973.9	90.02241886	29.85179595	1061+82	5	Ramp
25	3696233	493736.3	90.02291436	29.85114751	1064+65	1	Ramp?
26	3695931	493420.8	90.0238784	29.85028964	1069+00	5	Ramp
27	3695729	493239.6	90.02452004	29.84979768	1071+69	5	Ramp
28	3695533	493065.1	90.02514449	29.84932402	1074+43	5	Ramp
29	3694880	492559.1	90.02722465	29.84795304	1082+62	5	Ramp
30	3694317	492175.8	90.02901407	29.84691667	1089+44	5	Ramp
31	3694192	492070.6	90.02941109	29.84663132	1091+05	3	Ramp
32	3694043	491956.3	90.02988625	29.84632175	1092+90	5	Ramp
33	3693943	491882.3	90.03020432	29.84612134	1094+22	5	Ramp
34	3693605	491694	90.03127609	29.84561411	1097+95	3	New Levee
35	3693571	491640.7	90.0313845	29.84546875	1098+59	5	Ramp
36	3692064	490500.5	90.03618091	29.84238048	1117+50	5	Ramp
37	3691941	490438.5	90.03656871	29.8422139	1118+82	3	?
38	3691767	490284.8	90.03712424	29.84179664	1121+19	5	Ramp
39	3690554	489464.5	90.04097922	29.83957879	1134+97	5	Ramp
40	3690241	489164.8	90.04197584	29.83876441	1140+08	5	Ramp?
41	3690166	489122.2	90.04221366	29.83864952	1141+03	1	?
42	3690058	489024	90.04255938	29.83838293	1142+39	2	?
43	3689468	488591.3	90.04443664	29.83721128	1149+70	5	Low-Crest

Anomaly No.	LA South State Plane		Geographic		Station	Priority*	Description
	X, US ft	Y, US ft	Longitude	Latitude			
44	3689389	488537	90.04468709	29.83706453	1150+70	1	?
45	3689375	488521.5	90.04473245	29.83702234	1150+86	1	?
46	3689219	488413	90.0452252	29.83672877	1152+79	4	Near Ramp
47	3689059	488292.9	90.04573465	29.83640338	1154+79	5	Water Line
48	3688236	487696.2	90.04835337	29.83478811	1165+05	5	Ramp
49	3687845	487404.8	90.04959425	29.83399908	1169+86	5	Ramp
50	3687487	487139.9	90.0507344	29.83328157	1174+30	5	Ramp
51	3686829	486657.4	90.0528259	29.83197517	1182+40	5	Ramp
52	3686426	486362.1	90.05410842	29.83117563	1187+50	3	Ramp
53	3686290	486269.9	90.05453987	29.83092607	1189+15	5	Ramp
54	3685873	485957.5	90.05586453	29.8300798	1194+32	5	Ramp
55	3685687	485819.6	90.05645728	29.82970637	1196+63	1	Nitrogen Line?
56	3685332	485556	90.05758633	29.82899261	1201+04	5	Ramp
57	3685149	485437.7	90.05816787	29.82867276	1203+22	5	Ramp
58	3685021	485332.3	90.05857399	29.82838681	1204+89	5	Ramp
59	3684241	484742.7	90.06105488	29.82678951	1214+66	2	Low-U.Slope
60	3684145	484693.3	90.06135917	29.82665663	1215+70	5	Ramp?
61	3683861	484486.7	90.06226154	29.82609708	1219+28	5	Ramp?
62	3683472	484280.6	90.06349508	29.82554229	1223+75	3	Small Pos.-P.Slope

[a] Note: 1 = Highest priority.
5 = Lowest priority.

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13. SUPPLEMENTARY NOTES

14. ABSTRACT
This report presents the results of a geophysical study performed to locate buried debris within the levees on the west side of Algiers Canal approximately 8 km (5 miles) south of downtown New Orleans, LA. The levees are located adjacent to industrial and metal fabricating businesses. Reportedly, metallic debris, rubber hoses, concrete chunks, large pockets of shells, and other rubble have been found in these levees. A concern arose that debris and/or unmarked utilities located beneath or buried near the toe of the levees could affect the performance of the levee during flooding events. If a pipe or conduit exists under or within the levee, a possibility exists that it may fill with water during a flood event. If it does, and the conduit fails, it is possible that it may cause the levee to collapse either by piping material from within the levee or cause slope stability problems. It is also possible that buried utilities can act as potential seepage paths through the levee during high-water events. Buried debris and utilities need to be accurately located so that they can be removed or, in the case of a buried utility, re-routed or filled with grout. An electromagnetic (EM) induction survey using a Geonics EM31 terrain conductivity meter was conducted along the crest, slopes, and toes of the levee to locate anomalous conditions indicative of buried material. EM31 anomalies, presumed to be the location of buried debris, were mapped, and their coordinates tabulated for further interrogation.

15. SUBJECT TERMS
Algiers Canal
Electromagnetic induction survey
New Orleans levee
Levee performance
Geonics EM31
Anomaly detection

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